Study on Microstructure and Properties of a New High Temperature, High Strength and High Plastic Titanium Alloy

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Abstract: With the continuous development of aerospace technology, the demand for high temperature and high strength titanium alloys continues to increase, and the comprehensive mechanical properties of high temperature and high strength titanium alloys continue to improve. In this paper, a new high temperature, high strength and high plastic titanium alloy Ti-23Nb-6.7Co-5Cr-4Al(wt.%) was designed based on d-electron alloy design theory, and the alloy was prepared by vacuum induction magnetic levitation melting. The alloy has good high temperature (550℃) performance in the cast state, the tensile strength is 785±5 MPa, and the elongation reaches 35%±1%.

Keywords: Titanium Alloy, High Temperature, High Strength, High Plasticity

1 Introduction

Titanium and titanium alloy, because of their high specific strength, good corrosion resistance, good processing performance, good fracture toughness, good thermal stability and thermal strength and many other advantages, have been widely used in aviation, aerospace, navigation, petrochemical and other fields, so it is also known as "modern metal", "space metal", "Marine metal" and "strategic metal" [1].High-temperature titanium alloy can replace steel to achieve weight reduction effect, and can also be applied to engineering fields where the strength and service temperature of aluminum alloy cannot meet the requirements. As an excellent lightweight structural material, it is often used in the production of high-temperature parts of aerospace engines, such as engine blades, casing and roulette [2].In this paper, a new type of titanium alloy is designed based on the d-electron theory. The as cast titanium alloy has excellent strength and plasticity matching ability at room temperature, and has considerable tensile strength and excellent elongation at high temperature (550 ℃). It is worth noting that, unlike the previous high temperature titanium alloys, Sn, Zr, Si and other elements were not added in the design of the titanium alloy, which showed good high temperature performance.

2 Composition design

The design method of d-electron theory alloy can effectively study the electronic states in the local regions of various crystal structures, and give a correct description of various alloying effects [3]. The theory uses Bo and Md parameters to control the phase stability and properties of the alloy. B_o(Bond order) is used to characterize the strength of covalent bonds between titanium and alloying elements, and M_d(the metal d-orbital energy level) is a parameter closely related to the electronegativity of elements and the radius of metal bonds. The calculation formula is as follows [3]:

$$\mathrm{B_o} = \Sigma x_i (\mathrm{B_o})_i \tag{1}$$

$$\mathrm{M_d} = \Sigma x_i (\mathrm{M_d})_i \tag{2}$$

Where x_i is the atomic percentage of alloy element i.$(\mathrm{B_o})_i$ and $(\mathrm{M_d})_i$ are the B_o and M_d values of element i, respectively.

After consulting the data, four alloying elements, Nb, Co, Cr and Al, were determined [4]. The B_o and M_d values of the four elements in β-Ti are shown in Table 1. According to alloy design experience [3], β titanium alloys with high strength, easy processing and good plasticity generally have higher B_o value and smaller M_d value, because the larger the B_o value, the better the solid solution strengthening effect, and the smaller of M_d value, the more stable of β phase.

Table 1. B_o and M_d values of each elements in β-Ti

elements	B_o	M_d
Ti	2.790	2.447
Nb	3.099	2.424
Co	2.529	0.807
Cr	2.779	1.478
Al	2.426	2.200

In order to obtain stronger solid solution strengthening effect and more stable β phase, the B_o value and M_d value are set to be greater than 2.76 and less than 2.35, respectively. A new titanium alloy Ti-23Nb-6.7Co-5Cr-4Al(wt.%) was designed by referring to the research of researchers and the calculation of the range of B_o and M_d values [4].

3 Microstructure and mechanical properties of alloys

Figure. 1 shows the backscattering image of Ti-23Nb-6.7Co-5Cr-4Al(wt.%) alloy. It can be seen from the figure that the as-cast structure of the alloy is dendritic, and the secondary arm spacing is about 20 μm. The distribution of elements is investigated by energy spectrometer. The bright part is enriched. The results show that Co is segregated towards the dendrite edge, Nb is segregated in the dendrite center, and Ti, Al and Cr are evenly distributed.

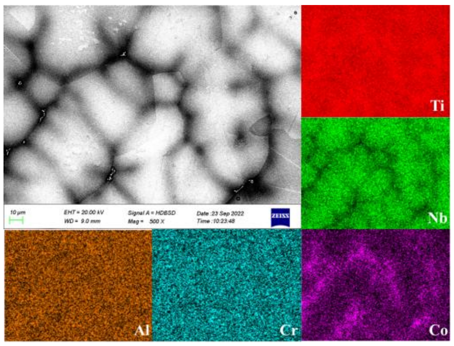

Figure 1. As cast microstructure and EDS analysis of alloys.

Figure. 2 shows the stress-strain curves at room temperature and high temperature (550℃) of Ti-23Nb-6.7Co-5Cr-4Al(wt.%) alloy in as-cast state. The tensile strength of the alloy at room temperature is 1083±5 MPa, the yield strength is 1025±6 MPa, the elongation is 18%±2%, the section shrinkage is 51%±3%, and the alloy has good comprehensive mechanical properties. At high temperature (550℃), the tensile strength is 785±5 MPa, the elongation is 35%±1%, and the section shrinkage is 87%±2%. The alloy has good elongation and section shrinkage at high temperature, and has the potential for superplastic development. The fracture at high temperature is shown in the figure, and the maximum dimples reach 20 μm. This is because the material underwent plastic deformation before fracture, and dimples were gradually formed with the expansion of fracture, which reflects the high toughness of the alloy.

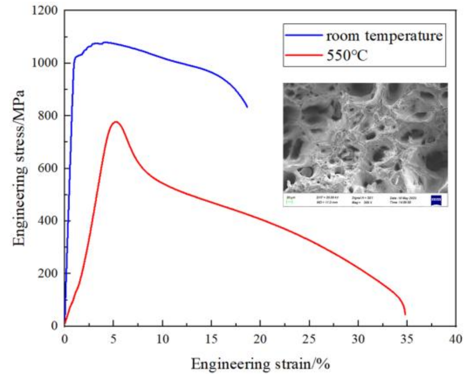

Figure. 2 Engineering stress-strain curve of alloy.

Conclusion

The as-cast Ti-23Nb-6.7Co-5Cr-4Al(wt.%) alloy has excellent properties at high temperature (550℃) (tensile strength of 785±5 MPa, elongation of 35%±1%, and high strength and plasticity), which has considerable development prospects. If Si and other alloy elements are added to the alloy, the high temperature performance will be more excellent, and it has an excellent research and development prospect.

References

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