

Corrosion Behavior of Ti-6Al-xV-2Sn-0.5Cu-yFe Alloys

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Abstract: Due to the high cost of smelting Ti alloys, a low-cost titanium alloy for marine engineering was designed in this study. The expensive V element in Ti-6Al-6V-2Sn-0.5Cu-0.5Fe (TC10) was replaced by the low cost Fe element which was the same as the V element as the β stable element. The corrosion behavior of Ti-6Al-xV-2Sn-0.5Cu-yFe alloys in strong reducing acid (5M HCl) was studied. It was found that although the corrosion resistance of titanium alloy decreased after replacing V with Fe, the corrosion resistance decreased little and the price of alloy raw materials was greatly reduced when only 1.5 wt.% Fe was used to replace 1.5 wt.% V in TC10.

Keywords: Ti alloy; Corrosion behavior; Low cost

1 Introduction

Titanium alloys have the characteristics of high corrosion resistance and high specific strength [1-3]. Therefore, it is also called marine metal. With the rapid development of marine engineering technology, the demand for improving the corrosion resistance of titanium alloys is becoming more and more urgent. However, due to the activity of titanium element, titanium alloy can only be melted in vacuum environment. Moreover, the preparation of titanium sponge is difficult. These two reasons lead to the high melting cost of titanium alloy. V element and Fe element are β -stable elements for Ti alloy. If the expensive V element can be replaced by cheap Fe element, the cost of Ti alloys will be greatly reduced. In this study, the corrosion resisting property of Ti-6Al-xV-2Sn-0.5Cu-yFe ($x + y = 6.5$, $x = 6, 4.5, 3, 1.5, 0$) alloys in strong reducing acid (5M HCl) was studied. This study provides a method for designing Ti alloys with high corrosion resistance and low cost for offshore engineering.

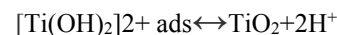
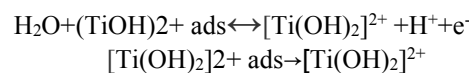
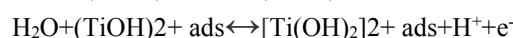
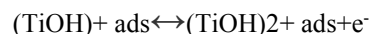
2 Experimental procedure

The purity of melting raw materials used in the preparation of titanium alloy was more than 99%. Ti alloy was melted by vacuum non-consumable arc furnace. The nominal composition of the melted Ti alloy was Ti-6Al-xV-2Sn-

0.5Cu-yFe ($x + y = 6.5$, $x = 6, 4.5, 3, 1.5, 0$). They were referred to as 0.5Fe, 2Fe, 3.5Fe, 4Fe, 6.5Fe. The electrochemical experiment was carried out in a three-electrode system with the help of an electrochemical workstation. The test solution was 5M HCl.

3 Result and discussion

Fig. 1 shows the polarization curves of five alloys. From Fig. 1, the anodic branches and the cathodic branches of the polarization curves of the five alloys in 5M HCl solution are similar. It shows that five alloys have similar reactions in electrolyte solution. The anode branches of the five alloys are divided into three stages: active dissolution region, active to passive transition region and passive region. In active dissolution region, Ti-6Al-xV-2Sn-0.5Cu-yFe alloys were active dissolved. The main chemical process involved was that Ti element changed to Ti^{3+} ion. In the active to passive transition region, the following reactions are dominant [4]. In the passivation region, an oxide film was formed on the surface of the five titanium alloys. In this region, the current density remained basically unchanged as the potential increased.



It can be seen from 6.5Fe that a certain polarization voltage is required to change from active to passive transition region to passive region. This shows that the passivation film formed on the surface of 6.5 Fe alloy is not stable. When the polarization voltage is about 1V, it can be seen that the perforation corrosion potential is observed in 5Fe alloy but no perforation corrosion potential was observed in other alloys. These indicate that the passivation films of 5Fe and 6.5Fe alloys have a weak ability to protect the surface.

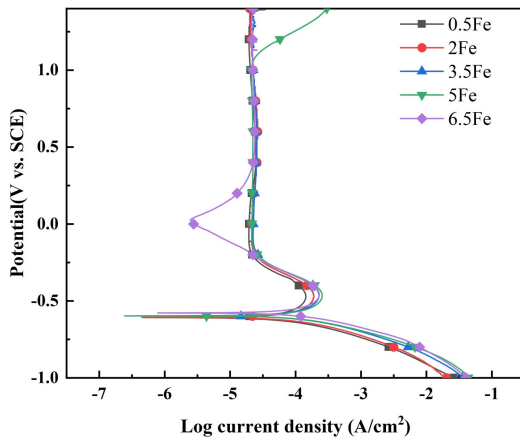


Figure 1. Polarization curves of Ti-6Al-xV-2Sn-0.5Cu-yFe alloys

Because Ti alloy is a common passivation metal. Therefore, the Tafel polarization curves of the five alloys show the characteristics of passive metals, so we use the Tafel extrapolation method to calculate the corrosion potential and corrosion current from the cathode branch.

As shown in Tab. 1, As the Fe element gradually replaces the V element, the corrosion current of the alloy in HCl gradually increases, and the corrosion potential generally shows a gradual increase trend. In general, from the perspective of corrosion kinetics, with the increase of Fe content, the corrosion resistance of the alloys in HCl is getting worse and worse. However, if only 1.5wt. % Fe element is used to replace the V element in the alloy, the corrosion resistance does not decrease much, but its composition decreases a lot. The corrosion current increased by about 36% when only 1.5 wt.% Fe was used instead of V. However, if the Fe content was increased by more than 3.5 wt.%, the corrosion current increased by about 68%.

Table 1. E_{corr} and i_{corr} of Ti-6Al-xV-2Sn-0.5Cu-yFe in 5M HCl

| | 0.5Fe | 2Fe | 3.5Fe | 5Fe | 6.5Fe |
|--|--------|--------|-------|-------|-------|
| E_{corr} (mV) | -0.601 | -0.605 | -5.79 | -5.88 | -5.78 |
| i_{corr} ($\mu A \times cm^{-2}$) | 0.072 | 0.098 | 0.121 | 0.119 | 0.123 |

In general, the Fe element is used to replace the V element in the titanium alloy, which reduces the corrosion resistance of the alloys. The reason for this phenomenon is mainly related to the segregation of Fe element in Ti alloys [5]. In the region where Fe element is enriched, the potential difference between the potential of this region and the potential of the alloy matrix increases. This phenomenon greatly increases the galvanic corrosion in the five alloys and increases the corrosion rate of the five alloys.

4 Conclusion

The use of cheap Fe element to replace the expensive V element in TC10 titanium alloy makes the corrosion resistance of titanium alloy worse. However, if only 1.5wt.% Fe element is used instead of V element, the corrosion performance of the alloy will not decrease much. Replacing the V element with 1.5 wt.% Fe element only increases the corrosion current of the alloy in 5M HCl by 36%. if the Fe content was increased by more than 3.5 wt.%, the corrosion current increased by about 68%.

5 Acknowledgments

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