Interface Reaction of ZTA15 Titanium Alloy and $CaZrO_3$ Investment Casting

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Abstract: Molten titanium alloys have extremely high chemical activity and are prone to interface reactions with precision casting shells during the casting process, resulting in a decrease of the surface quality of the castings. Now Y_2O_3 is widely used as casting shells, but it's so expensive that there is an urgent need for a low-cost shell surface layer material to replace Y_2O_3 to reduce the cost of titanium alloys precision castings. In this paper, $CaZrO_3$ was used to prepare two types of titanium alloy precision casting shells, namely neutral binder surface layer and acidic binder surface layer, for TA15 titanium alloy precision casting. The results indicate that the use of neutral binders can lead to the presence of a certain thickness of Zr diffusion layer and O diffusion layer on the surface of castings, while the use of acidic binders only results in an O concentration zone on the surface of castings, without a Zr diffusion layer. At the same time, there is a certain thickness of tissue transition zone on the surface of the casting, among which the interface structure of the acidic binder surface layer casting is much better than that of the neutral binder surface layer casting.

Keywords: Interface reaction; Investment casting

1 Introduction

Titanium alloys are widely used due to their good properties in strength, toughness, formability, weld-ability, corrosion resistance and biocompatibility[1]. Investment casting is the most important casting process for titanium alloys. Currently, more than 90% of small and medium-sized titanium alloy castings use investment casting technology[2]. However, Limited by the high cost of surface material such as Y_2O_3, there is an urgent need for a low-cost shell surface layer material to replace Y_2O_3 for large-scale of titanium alloy. According to Ellingham diagram[3], $CaZrO_3$ is a promising refractory material for titanium alloy investment casting.

In this paper, The interface reaction between the surface layer materials prepared by $CaZrO_3$ combined with different binders and TA15 was mainly studied.

2 Experimental procedure

In the experiment, silica sol and zirconium acetate were used as binders, and 325 mesh $CaZrO_3$ was used for the surface layer. Neutral surface layer shells with a powder to liquid mass ratio of 3.5:1, 3.25:1, and 3:1 were prepared using silica sol, as well as acidic surface layer coatings with a powder to liquid mass ratio of 1.75:1. 100 mesh, 60 mesh, and 30 mesh alumina coarse sand were used for the back layer sanding. Use this shell to cast TA15 titanium alloy, and then perform SEM, XRD and metallographic analysis on the obtained titanium alloy and shell.

3 Result and discussion

Microscopic organization

The microstructure of the casting is shown in Figure 1. It can be seen that the microstructure of the sample is a layered Weinstein structure, but there is a clear boundary transition region in the surface area. The transition zone structure is consisting of columnar crystal structures arranged along the direction of heat flow. This is mainly due to the chilling action of the shell and the presence of a large number of heterogeneous nucleation at the edges.

By comparing Figures 1(a), (b), and (c), it can be observed that as the powder to liquid ratio gradually decreases, the thickness of the edge tissue transition region increases from 320 μm in 1# to 216 μm in 2#, and then to 290 μm in 3#. The columnar crystal structure at the edge also changes accordingly, with columnar crystal grain widths of 12.18 μm, 11.59 μm, and 11.96 μm, respectively. From Figure 1(d), it can be observed that the interface quality of the alloy with an acidic surface layer is higher than that with a neutral surface layer. The transition region of the microstructure is only about 218 μm, and the structure is uniform without the appearance of obvious coarse columnar crystals.

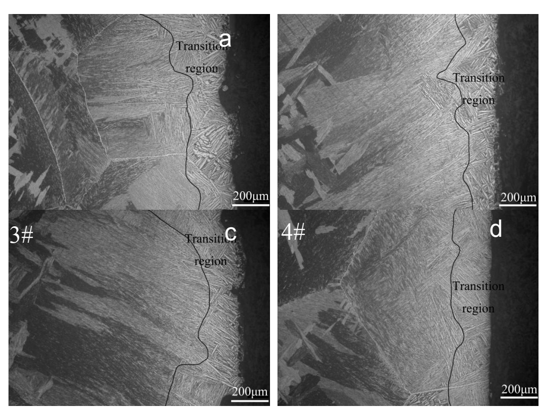

Fig.1 Surface microstructures of specimens:(a)1#, (b)2#, (c)3#, (d)4#.

The scanning electron microscope at the edge of the sample is shown in Figure 2. Different interface reaction layers were found on the surfaces of each sample, with a reaction layer of about 50 μm in 1#, a thicker reaction layer of about 60-90 μm in 2#, and a relatively thicker reaction layer of about 30 μm in 3#. However, the reaction layer of the acidic surface layer is thicker, higher than 50 μm. The results observed in the metallographic structure of the sample with a neutral surface layer are consistent, while the acidic surface layer structure is relatively thick, indicating that the acidic binder reacts with $CaZrO_3$ during the shell hanging and calcination processes, producing substances that can dissolve with the titanium liquid and promote the crystallization of the titanium alloy.

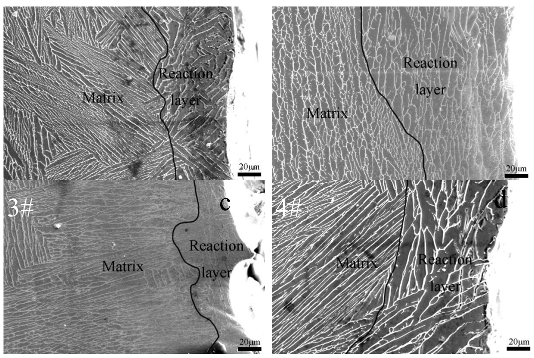

Fig.2 Surface SEM images of samples:(a)1#，(b)2#，(c)3#，(d)4#.

Phase analysis

The XRD results of four sets of samples are shown in Figure 3. Except for the α - Ti group, the surface of 1#, 2#, 3#, and 4# mainly consists of various oxides of Ti and V, as well as $CaCO_3$ and $CaZrO_3$ attached to the surface. The surface layer material O diffused into the sample and reacted with the matrix, while the oxidation of various elements in 4# using an acidic surface layer was relatively severe, and even the Ti peak was lower. The various oxide peaks of titanium were higher than Ti.

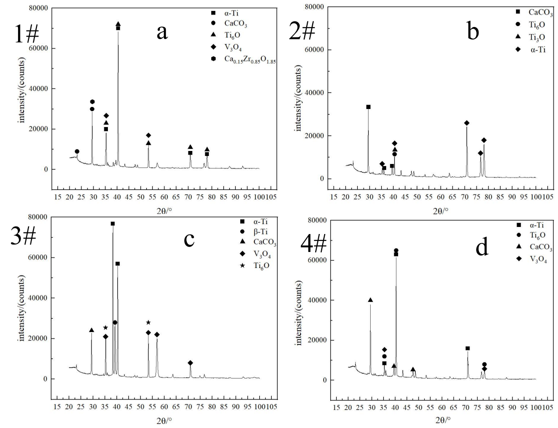

Fig.8 XRD pattern of samples:(a)1#，(b)2#，(c)3#，(d)4#.

4 Conclusion

There is a transition region of 200-320 μm on the surface of the casting, with the grains mainly being columnar. The thickness of the transition zone of the neutral surface layer is 216-320 μm, while the transition zone of the acidic surface layer is only about 218 μm. The structure obtained by the acidic surface layer is significantly better than that of the neutral surface layer.

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