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Evaluation of the α-case with Titania Mold for Titanium Investment Casting

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The brittle α-case must be removed by chemical milling because it reduce the mechanical properties. The aim of this study is to evaluate and prevent α-case formation as a mold materials. Titania which was most of the α-case phase was generated by addition of titanium powder or simply added on the Al_2O_3 mold for preventing of α-case. The titanium casting surface was investigated by using optical microscopy (OM). Composition and morphology of mold was confirmed by using X-ray diffraction (XRD) and field emission scanning electron microscope (FE-SEM). The castings using titanium added mold (Al_2O_3+xTi) was effectively reduced the formation of α-case. However, the chemical stability of titania add mold (Al_2O_3+x TiO_2) that has almost identical composition to titanium added mold had different effect of α-case formation.

Keywords: *Titanium, Investment casting, Titiania added mold, titanium added mold, α-case*

1. Introduction

Because of the poor machinability and workability, investment casting was widely used for producing complex and near net shape titanium product. Investment casting processes has excellent reproducibility of castings within close dimensional limits [1]. However, the titanium was extremely reactive with mold material, resulting in α-case. α -case was formed by the diffusion of oxygen and metallic element from the mold to titanium. And the α-case were composed of titanium oxide and intermetallic compound [2]. The formation of the α-case on casting degraded the mechanical properties such as ductility by acting as cracks initiate site [3]. Therefore the α-case usually removed by chemical milling before use. But the milling process was expensive and limits the dimensional tolerance. In this study was to suppress the α-case by generating or adding titania on the mold. The formation of titania in the mold side was induced during the mold firing process or simply added to slurry.

2. Experimental procedures

Alumina, titanium and titania were used for primary coating. In order to produce TiO_2 in the mold, the 50 % of titanium or titania were added to the alumina plus colloidal SiO_2 slurry respectively. Primary coating process was repeated twice. Backup coating underwent three times with chamotte slurry over at intervals of 4hour. The mold was dewaxed in an autoclave at 150 MPa and fired in furnace at 950ºC. Titanium (ASTM B-348, grade 2) was melted in the water-cooled copper crucible. The titanium, weighing 120g, was placed on top of the copper crucible. And the mold was located inside the copper crucible for the drop of titanium melts. The phase identification of molds was analyzed by x-ray diffractometer (M18XHF-SRA, Mac Science). The thickness of the α-case was determined using a micro Vickers hardness (MVK-H2, Mitutoyo) and OM (PME 3, Olympus). In our work, the micro Vickers hardness test was performed with 50 μm from the casting surface to 1000 μm, applying a 100 g load. Macrostructure and composition of before and after mold surface were examined by FE-SEM (JSM-7600F, JEOL).

3. Result and discussion

3.1 Analysis of mold composition

Figure 1 shows the XRD spectra of various mold materials. The composition of Al_2O_3 and Al_2O_3+ $50TiO_2$ mold was not changed, indicating that the Al_2O_3 and TiO_2 were stable phase after mold firing condition. While, Al_2O_3, TiO_2 and Ti_5Si_3 were found in Al_2O_3+50Ti mold. TiO_2 was caused by reaction between the atmospheric oxygen and titanium during mold firing. Also, the reaction between the titanium and colloidal silica resulted in formation of Ti_5Si_3.

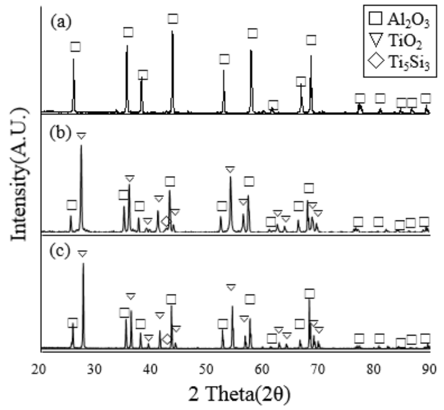

Fig. 1 XRD results of refractoty mold (a) Al_2O_3, (b) Al_2O_3+50Ti and (c) Al_2O_3+50TiO_2

3.2 Thickness of α-case

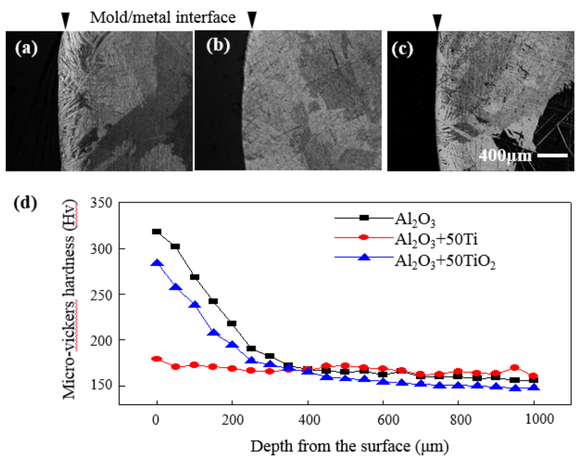

Fig. 2 Titanium castings with difference mold (a) Al_2O_3, (b) Al_2O_3+50Ti, (c) Al_2O_3+50TiO_2, and (d) Micro Vickers hardness of castings

Figure 2(a) appeared needle like α-case between the castings and the Al_2O_3 mold. However, the castings made with the Al_2O_3+50Ti mold had no α-case. Also, castings made with Al_2O_3+ 50TiO_2 mold has small amount of α-case, compared to Al_2O_3 mold. Figure 2(d) exhibit a micro Vickers hardness profile in titanium castings depending on the depth from the surface. Castings made with Al_2O_3 mold had 350µm α-case depth. However, the α-case was only 50µm with Al_2O_3+50Ti mold. Also, α-case was 300µm when Al_2O_3+50TiO_2 mold was used.

3.3 Effect of TiO_2 on α-case formation

Both Al_2O_3+50Ti and Al_2O_3+50TiO_2 mold of composition was nearly identical. However, effect of α-case was different. Mold surface morphology was analyzed by FE-SEM. Figure 3 shown the FE-SEM image of mold surface before and after casting. Before casting, Al_2O_3 and Al_2O_3+50TiO_2 mold surface contained homogeneously distributed Al_2O_3+SiO_2 and TiO_2+SiO_2. In Al_2O_3 +50Ti mold, TiO_2 phase shaped all pointed, in conjunction with Al_2O_3+SiO_2 phase, were observed. After casting, Al_2O_3+SiO_2 was not observed and residues in mold was confirmed AlO. TiO_2 phase was also changed into the TiO because oxygen was diffused into melts. Oxygen solubility of the titanium contact with TiO_2 phase was 1.6% at 1770ºC. However oxygen solubility of the titanium was changed into 0.14% when titanium contacted with TiO phase at 1750ºC [4]. As a result, TiO_2 phase on the mold reduced α-case formation. However, the effect of TiO_2 phase in the Al_2O_3+50Ti and Al_2O_3+ 50TiO_2 mold was apparently contradictory result. That was supposed to be distinguished morphology between Al_2O_3+50Ti and Al_2O_3+50TiO_2 mold.

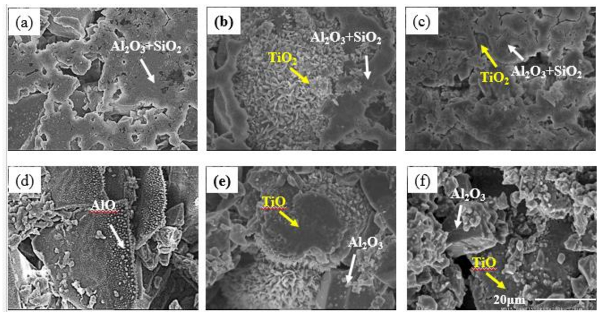

Fig. 3 FE-SEM image of mold surface (a) Al_2O_3, (b) Al_2O_3+50Ti, (c) Al_2O_3+ 50TiO_2 before casting, (d) Al_2O_3, (e) Al_2O_3+50Ti, (f) Al_2O_3+ 50TiO_2 after casting,

4. Conclusions

Composition of Al_2O_3+50Ti and Al_2O_3+50TiO_2 mold was nearly identical because of the titanium oxidation. While, effect of α-case formation was different. That was supposed that the TiO_2 had different shape on the mold.

References

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