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Casting Solidification Structure of Titanium and Titanium Alloys using Oxide Cements Mold

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The purpose of this study is to evaluate the casting solidification structure of titanium and titanium alloys by using some oxide cements mold. The molten metals are commercial pure titanium, α+β type Ti-6Al-4V alloy, and β type Ti-22V-4Al alloy. These were melted by arc furnace. The mold was made from the lost wax process using commercial alumina, magnesia and zirconia cements.

As for manufactured castings, Vickers hardness distribution of the section and metallographic microstructure were investigated. From these results, it was discussed about the difference of solidification structure and the difference of reaction layer between oxide cements and titanium or titanium alloys.

Keywords: *titanium alloy, Vickers hardness, optical microstructure, ceramic cements mold*

1. Introduction

The working cost of titanium and titanium alloys were generally high, so that using casting process is one of the effective method to reduce the cost of titanium products. The study on casting of titanium and its alloys and manufacturing its products have already performed [1-3]. However, to deepen knowledge about casting solidification structure or reaction layer formed by each ceramics mold in titanium and its alloys more ever, it leads to improve the casting technology of titanium and its alloys.

The molten metals are commercial pure titanium (CPTi), α + β type Ti-6Al-4V alloy (Ti6Al4V), and β type Ti-22V-4Al alloy (Ti22V4Al). These titanium alloys ware ternary alloys indicate different phase constitution of the α and β phases with different content of Al and V. There is a metallurgical significance for discussing about the difference in the solidification structure by the difference between the additional element to titanium and the phase constitutions. Refractory cements mold using the casting were commercial alumina (Al. mold), magnesia (Mg. mold) and zirconia (Zr. mold). Although Zr. mold is considered to be suitable for the purpose from the Ellingham diagram, it is more expensive than other molds.

The purpose of this study is to evaluate the casting solidification structure of titanium and its alloys from the fundamental metallurgical scope.

2. Experimental Procedure

The used molten metals were CPTi, Ti6Al4V, and Ti22V4Al. The Al. mold, Mg. mold and Zr. mold were used in this casting process. The molds were made mix mud cements, and pattern made by wax was embedded in mix mud, and made them dry. The pattern was removed by heating. The molds were heated at 1473 K for Al. mold, 1573 K for Mg. mold, and 1673 K for Zr. mold, and hold at an hour for the purpose of strengthen the mold.

The molten metals were made by the vacuum ark furnace using a nonconsumable W-electrode. These were poured in the molds under the vacuum, and castings were made by removing the molds. The castings were embedded in epoxy and it was sliced for the purpose of consequent evaluation. **Fig.1** shows the sliced specimen of CPTi casting using Mg. mold.

The sliced specimens were polished until obtain the mirror surface using alumina abrasive powder. Vickers hardness test was performed with a load of 1kgf to obtain the differences between center of specimen and near the boundary of the molds. In addition, the change of Vickers hardness from the boundary of the molds to inner side were investigated with the step of 20μ m at a load of 0.05 or 0.1 kgf.

Cross section microstructure of the sliced specimens were observed by microscope after the etching. The etchant using this process is HF (5%vol.) + HNO_3 (5%vol.) + water (bal.).

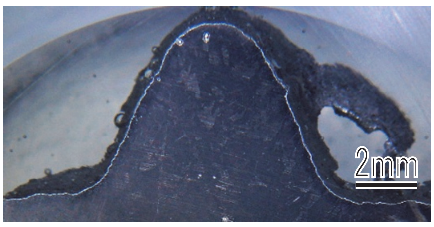

Fig.1 CPTi casting using Mg. mold.

3. Results and discussion

The change of Vickers hardness on center or edge of specimens with the kind of alloys and molds were shown in **Fig.2**. Although the hardness of CPTi using Al. mold indicated higher value at both edge and center, that of titanium alloys were not higher at the center of the specimens. In Ti6Al4V, the hardness of Mg. mold was comparatively higher. That of Zr. mold was lower at both edge and center. On the contrary in Ti22V4Al, that of Zr. mold was higher than that of Mg. mold. To evaluate the hardness distribution more detail, the hardness from the mold boundary was investigated. The change of Vickers hardness with the distance from the mold boundary were shown in **Fig.3**. In Ti6Al4V, the hardness of the area until 50 μm from the Mg. mold was especially high, and it was indicated over 500HV after that. On the other hand, substantial change of hardness from the Zr. mold was not occurred. In Ti22V4Al, substantial change of hardness was not occurred by using Mg. mold. On the contrary by Zr. mold, the area until 250 μm from the boundary indicated especially higher values, and it was indicated under 400HV after the inner side which was almost the same tendency of Mg. mold. These differences of the hardness from the mold boundary was considered to be caused by institutional depth of the oxygen and formation of a compound layer which was affected by the phase constitution or content of alloying elements of titanium alloys.

To compare and examine the difference of the hardness and the difference of the microstructure, observation by optical microscope was performed. **Fig.4** shows optical microstructure of the specimens from the mold boundary. Ti6Al4V using Mg. mold (a), boundary area of 50 μm form the mold was observed. The area is equivalent to the area of higher hardness. Typical acicular microstructure was formed at the inner side. On the other hand using Zr. mold (b), boundary area of 200 μm was observed, though the area did not affect the hardness considered from the results of hardness. Ti22V4Al using Mg. mold (c), any boundary area was not observed. Only of grain boundary of β phase was observed. On the contrary, that using Zr. mold (d), boundary area of 200 μm from the mold was observed. The area was considered to be the area that indicated especially higher hardness.

To discuss about the results more detail, there are a need to evaluate the elements distribution, oxide or compounds layer.

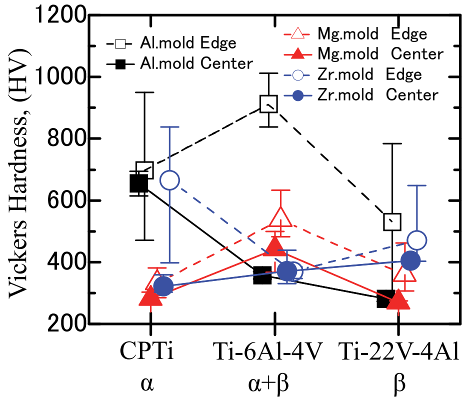

Fig.2 Change of Vickers hardness on center or edge of specimens with the kind of alloys and molds.

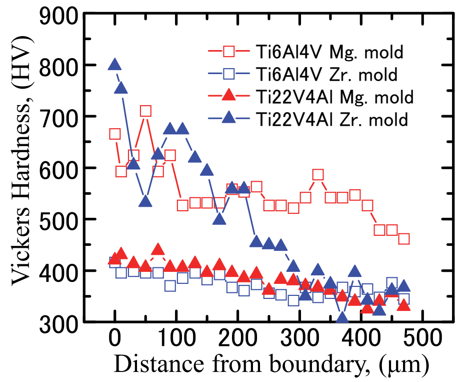

Fig.3 Change of Vickers hardness with the distance from the mold boundary.

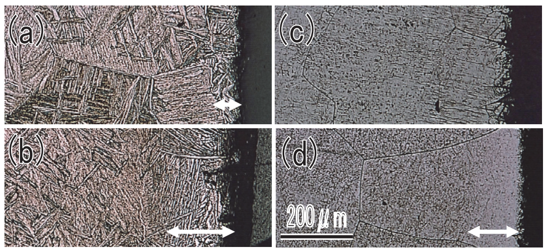

Fig.4 Optical microstructure of specimens from the mold boundary.

4. Conclusion

While the hardness of Ti6Al4V using Mg. mold was higher than Zr. Mold, reverse results were obtained by Ti22V4Al. Formation of reaction layer thickness or oxygen institutional depth are different from the alloying element content or phase constitution in a kind of titanium alloys. This metallurgical differences were considered to cause the hardness distribution.

References

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