〔Original〕 Matsumoto Shgaku 21 : 202~207, 1995
key words : Titanium — Mold temperature — Castability

Effect of Mold Temperature on the Titanium Casting

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Summary

The purpose of this study was to evaluate the titanium castability with a vacuum pressured type casting machine. We tested ethyl-silicate bonded investment "TITAVEST-PS" of metal frame work. Four different mold temperatures (room temperature, 300℃, 600℃, and 900℃) were prepared for the present study, and casting was done in five times in each condition. When the mold temperature increased, high percentage of castability was gained. Mold temperature showed a highly significant ($p<0.001$) correlation on the castability. These results indicate that high performance of castability on the titanium was achieved when the mold temperature increased by using vacuum pressured type casting machine.

Introduction

We have been examing the effect of casting conditions on tiranium castability[1-3] because titanium has a serious problems for dental casting. If the molten titanium's temperature is high, the chemical activity becomes too high. Previously, we reported about reactions of titanium castings surface[4,5]. The result of this report showed that, when the mold temperature was low, the good mechanical properties were gained. However, When casting at room temperature, this technique demands the much time must be set a side for burn out to be completed. We also tested the effect

(accepted for publication on July 5, 1995)

of mold temperature on castability using a plate type pattern. The result of this research being that, high percentage of castability was gained in all conditions. The purpose of this prevent study was to assess the pure titanium castability using a mesh type pattern at various mold temperatures, cast with a vacuum-pressured type machine.

Materials and Methods

Table 1 shows the materials and methods employed in this study. Pure titanium used was JIS grade 2. An Vacuum-pressured type casting machine CYCLARC was employed. A mesh grid type pattern was performed for measuring the castability[6,7]. The pattern chosen for the present study was originally designed for metal frame work. Sprue, 1.26 mm in diameter, was attached to the mesh pattern according to the spruing conditions shown in Figure 1. The wax pattern was attached to a suitable crucible former. The wax pattern was invested according to manufacturer's instructions. After the heat shock, surplus alcohol in the mold was evacuated. The casting mold was heated in a burn-out electric furnace under four different mold temperatures (room temperature, 300°C, 600°C, and 900°C). The casting was carried out in a vacuum-pressure casting machine under argon (Ar) gas pressure of 1.5 kgf/cm^2. The calculating method of castability was undertaken by percentages of mesh grid corner castings to mesh grid corner of original wax pattern. Single regression analysis was adapted on a mean, standard deviation, coefficient of variation, mold temperature and castabiliy from a value provided, and regression line and coefficient of correlation were analyzed.

Results

Overall increase of castability was shown when the mold temperature increased (Figure 2). Castings at the room temperature, and 300°C produced smooth surfaces. At 600°C, and 900°C produced rough surfaces by the reaction with the mold was shown (Figure 3). Table 2 shows a mean, standard deviation and coefficient of variation of castability calculated in this study. It showed the higher the mold temperature increased, the better the castability of titanium casting. When mold temperature increased, the coefficient of variation showed smaller, and the castability became stable and high level of performance is achieved. Single regression analysis from a mean is shown in Figure 1. The coefficient of correlation was 0.999 and significant ($p<0.001$) correlation between castability and mold temperatures was shown.

Discussion

When mold temperature was increased, high percentage of castability was gained. This research showed the same result like the conventional dental casting alloys[8]. However, this result didn't agree with our report published before. The report described that mold temperature did not affect to castability using a plate type pattern. Table 3 shows a comparison between mesh type patterns and plate type patterns with volume-surface area ratio (V/S ratio). The mesh pattern V/S ratio is bigger than the plate pattern. Namely, it seems the effect of V/S ratio on the castability is found in this study. Especially, molten titanium flow-in speed into casting mold decreases in case of mesh patterns[9]. The coefficient of correlation was 0.999 and significant correlation of the castability between mold temperatures was found. This result indicates that mold temperature seems to be one of the greatest prime factors for titanium castability. On the other hand, the surface property of castings which were cast under room temperature and 300°C produced a smooth surface. Castings at 600°C and 900°C produced a rough surface because of the reaction of casting mold

Table 1. Materials and Methods

Casting machine	Pressure and vacuum type CYCLARC	MORITA
Wax pattern	RN II	Dentaurum
Sprue	⌀ 1.26 mm Length 5 mm	Murakami
Mold material	Titavest PS	MORITA
Mold condition	Pattern-mold bottom distance 10 mm Length 60 mm	
Titanium	JIS Grade 2 (KS-50)	Kobe Steel Ltd.
Casting pressure	1.5 kgf/cm²	
Mold temperature	Room temperature, 300℃, 600℃, 900℃	

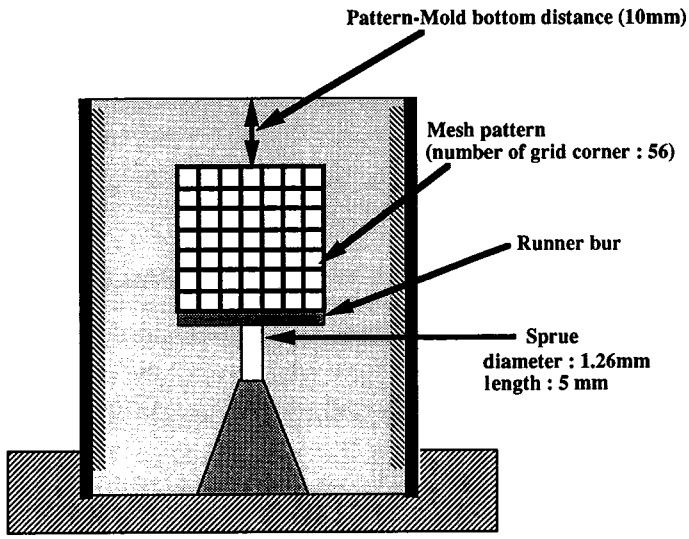

Figure 1. Schema of investing condition with mesh grid pattern

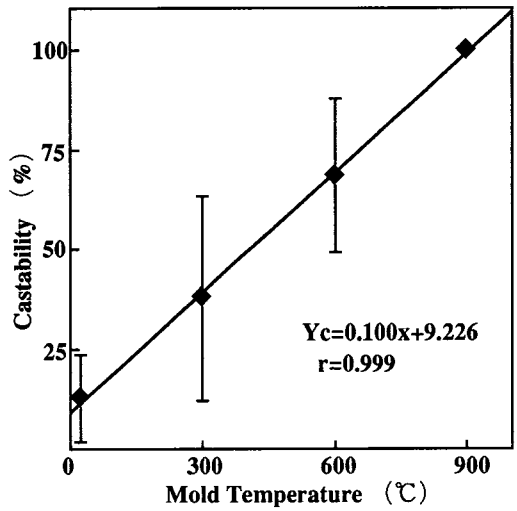

Figure 2. Effect of casting mold temperature on titanium castability

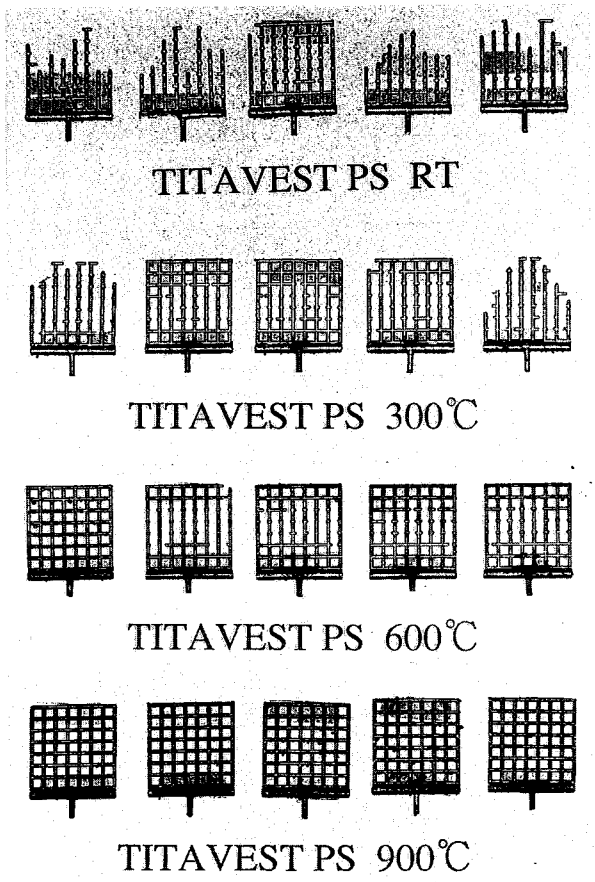

Figure 3. Appearance of titanium castings under different mold temperature (number of grid corner : 56 : As cast)

Table 2. Effect of mold temperature on titanium castability (Mean, SD, CV, correlation coefficient)

Mold temperature (℃) / Mold investment		R. T	300	600	900
Titavest PS	Mean	12.86	37.86	68.57	100
	SD	10.89	25.61	19.26	0
	CV	84.71	67.65	28.08	0
Correlation coefficient : 0.999*					

Mean, CV : (%) n=4 *P<0.001
R. T : Room temperature

Table 3. Volume-Surface ratio of pattern

Pattern	V/S
Mesh	0.20
Plate (19×19×1.5 mm)	0.71

components. The casting mold used in this research contained Silica (SiO_2), Alumina (Al_2O_3), Magnesia (MgO). In particular, it is reported that SiO_2 is to be able to react easily with titanium in these kinds of compositions and this result agrees with our past report[10].

These results suggest that mold temperature is the most affective condition for titanium casting. However, if mold temperature is too high, castings with low quality will be created. Therefore, mechanical properties of titanium castings can be easily changed at high temperature.

Conclusion

Mold temperature is most affective condition for titanium casting, when assessed by a mesh type pattern. However, if mold temperature is too high, castings with low quality will be created.

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抄録：チタン鋳造における鋳型温度の影響

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本研究の目的は加圧吸引型鋳造機を用い，異なった鋳型温度におけるチタンの鋳込率を比較検討を行うことである．埋没材は金属床用のエチルシリケート系埋没材“TITAVEST-PS”を使用した．鋳型温度は室温，300°C，600°C，900°C にて比較検討を行い，各条件にて5回鋳造を行った．その結果，鋳型温度が増加すると高い鋳込率が得られ，鋳型温度と鋳込率は優位な正の相関関係（$p<0.001$）を示した．以上の結果から加圧吸引型鋳造機にてチタン鋳造を行った場合，鋳型温度が増加すれば高い鋳込率が得られることが示唆された．