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Studies on the Castability of Pure Titanium (Part 4) Castability in case of casting molds with low gas permeability

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Summary

The purpose of this study was to evaluate the influence of casting molds with low permeability on the castability of pure titanium with an all directional pressured type casting machine. Two types of phosphate bonded casting molds were used, T–INVEST and T–INVEST C&B. We reported high performance of castability of pure titanium with an all directional pressured type casting machine, if the permeability of the investment was lower as possible[4]. Specially prepared metal sealed rings to decrease gas permeability of casting mold were used. Two sizes of sprue condition were prepared, 1.26 and 1.48mm, under a casting pressure of 8 kgf/cm^2. Five sizes of casting molds were prepared with mold diameters of 25, 35, 45, 55 and 65 mm. The following results were obtained: A high percentage of castability was gained in T–INVEST using a high gas permeability casting mold with the sealed ring. A low percentage of castability was gained in T–INVEST C&B using a low gas permeability casting mold with the sealed ring. Back pressure action in the casting mold of T–INVEST C&B seemed to produce negative effects regarding the castability. These results indicated that the sealed ring was effective to promote pure titanium castability with a mold of high permeability.

Introduction

These are many studies[1~3] about castability of pure titanium. We analyzed pure titanium castability in 2 phosphate bonded investments under various casting conditions with an all directional pressured type casting machine[4,9~12]. We reported that a high percentage of castability of titanium was gained with the investment of low permeability using the casting machine of an all directional pressured type.

In casting molds with high gas permeability, large amounts of casting mold materials had to be used to obtain the optimal permeability for successful casting.

To overcome this problem, the authors of this study developed a specially sealed ring to purge air exhaust from the bottom of the mold besides the lateral wall and evaluated the pure titanium castability under various conditions.

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Table 1 : Materials used in this study

Casting machine	All directional pressured type AUTOCAST HC-Ⅲ	GC
Wax pattern	RN Ⅱ	DENTAURUM
Sprue	Diameter 1.26 mm Length 5 mm	Murakami
Mold material	T-INVEST (Phosphate-bonded)	GC
	T-INVEST C&B (Phosphate-bonded)	GC
Ring	Diameter : 25, 35, 45, 55, 65 mm High : 60 mm	Itoh engineering
Titanium	JIS Grade 2 (KS-50)	Kobe Steel Ltd

Materials

1. Materials used in this study are shown in Table 1.

Pure titanium used was a JIS grade Ⅱ ingot (9 mm height, 25mm of diameter and 20.026 ± 0.033 g weight: KS-50, Kobe Steel Ltd.)

The wax pattern for measuring the castability was the same as to the previous study[5]. Metal sprue (Murakami Co.) was set at as 5 mm in length with diameters of 1.26 and 1.48mm. Two types of phosphate bonded investments were employed; T-INVEST and T-INVEST C&B; GC Co). Specially designed sealed rings with detachable basal plates were prepared (Itoh Engineering Co). An All directional pressured type casting machine (AUTO CAST HC-Ⅲ, GC Co.) was used (Table 1).

2. Making test pieces

1) Wax pattern and spruing

Wax pattern and spruing was done in the manner reported in the previous study[5].

2) Investing, burning out and casting

Investing and burning out were performed according to the manufacturer's instructions. In T-INVEST, the liquid/powder ratio was adjusted to 0.14, burn-out was carried out for 3 hours at 800℃ with tempering of 30min, then at 1050℃ for 3 hours with tempering of 1 hour, and then cooled to room temperature before casting.

In T-INVEST C&B, the liquid/powder ratio was adjusted to 0.13, burn-out was carried out for 30 min, at 250℃ with tempering for 1 hour, then at 800℃ for 1 hour with tempering for 1 hour, and then cooled to room temperature before casting.

Casting pressure was set at 8 kgf/cm^2 in both investments.

Methods

Condition 1 : Comparison between the casting with the sealed ring and the ringless casting.

Sealed ring investing was carried out in both T-INVEST and T-INVEST C&B with the mold sizes of 25, 35, 45, 55 and 65mm. Wax pattern was situated 10 mm from the bottom of the mold (Fig. 1, Table 2).

Condition 2 : Comparison of the heat conductivity of the ring.

A special bottom closed ring with radiation fins for dispersing heat was prepared (Fig. 2, Table 2).

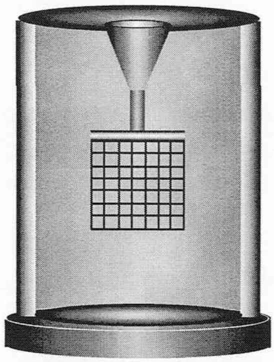

Fig. 1 : Schematic illustration of bottom seal ring

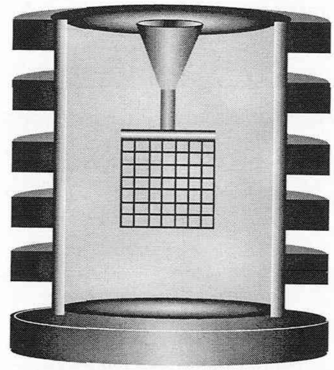

Fig. 2 : Schematic illustration of bottom seal ring which has cooling function

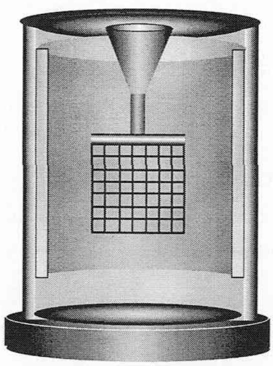

Fig. 3 : Schematic illustration of bottom seal ring with influence of delayed gas purge and the diameter of sprue

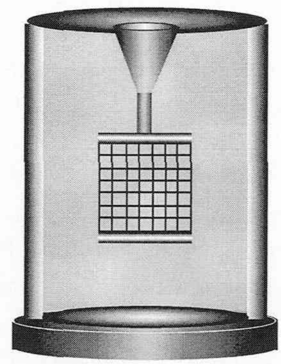

Fig. 4 : Schematic illustration of bottom seal ring and the wax pattern was given the runner bar which assessment of the reservoir to the wax pattern

Table 2 : Methods

Condition 1	Sealed ring employed in each casting mold
Condition 2	Sealed ring with radiator for comparing thermal conductivity
Condition 3	Sealed ring with influence of delayed gas purge and the diameter of sprue condition Sprue : 1.26 mm Sprue : 1.48 mm
Condition 4	Sealed ring and the wax pattern was given the runner bar which assessment of the reservoir to the wax pattern

T-INVEST C&B was assessed with the condition of mold diameter set at 45mm and the wax pattern situated 10mm from the bottom of the mold.

Condition 3 : Influence of delayed gas purge and the diameter of sprue condition.

In this situation,the casting liner was applied to the inner surface of the sealed ring (Fig. 3, Table 2).

Sprue diameters were 1.26 and 1.48mm. The diameter of the casting mold was 45mm with 10mm between the wax pattern and the bottom of the mold.

Condition 4 : Assessment of the reservoir to the wax pattern.

Wax reservoir for assisting the casting was examined. Additional runner bars were prepared on both sides of the upper and lower margin of the wax pattern as a reservoir[13] (Fig. 4, Table 2). Wax pattern was situated 10mm from the bottom of the investment with the mold diameter of 45mm in T–INVEST C&B.

Assessment of the castability

At every condition, casting was executed 5 times and the castability was calculated[5].

Mean, standard deviation and coefficient of correlation were calculated. All results were compared by the one way analysis of variance : castability was assumed to be the dependent variable and the above 4 conditions the independent variables.

Results

1. Comparison between the casting with the sealed ring and the ringless casting.

Castability was shown with T–INVEST and T–INVEST C&B cast in the sealed rings (Fig. 5) and the ringless mold[4] (Fig. 6).

T–INVEST showed 100% castability with the sealed ring at every condition.

T–INVEST C&B showed unsuccessful castability at every mold condition with sealed ring casting compared to ring less casting ($P<0.05$, Fig. 8). The mold diameter did not influence the castability.

2. Influence of heat conductivity of the mold.

In cases with special bottom closed rings with radiation fins for dispersing heat and sealed rings, there was little difference in castability (Fig. 7, 8).

3. Influence of delayed gas purge and the diameter of sprue condition.

There was little difference between castability in cases in which a casting liner applied to the inner surface of the sealed ring and ringless mold in sprue conditions of 1.26 and 1.48mm. However, the castability was significantly higher both with the sprue of 1.26 and 1.48mm ($P<0.05$, Fig. 8) compared

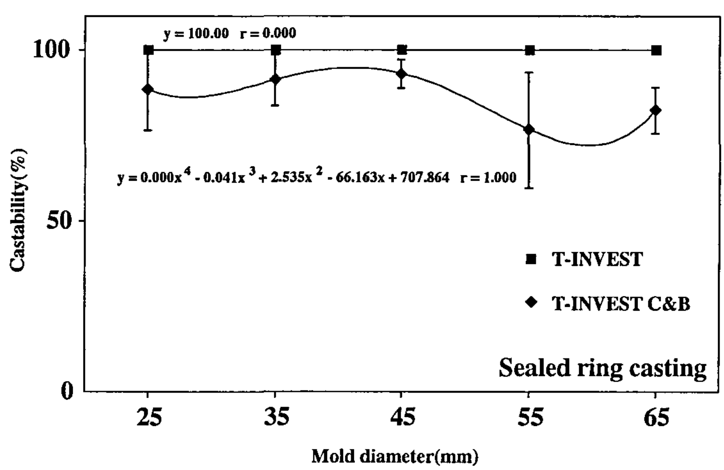

Fig. 5 : Effect of mold diameter and ring condition on the titanium castability

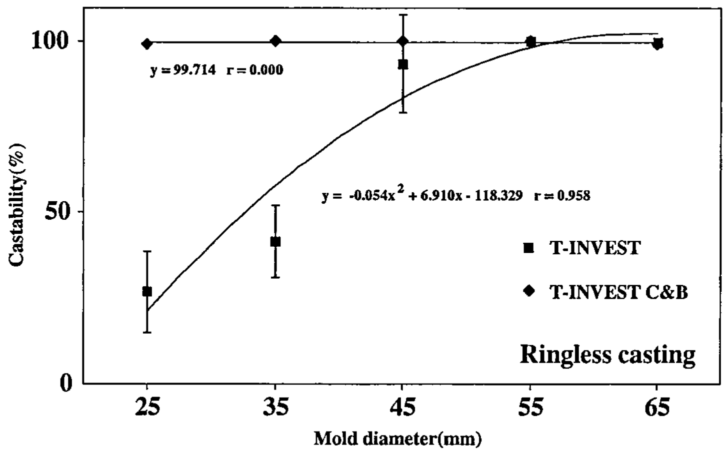

Fig. 6: Effect of mold diameter and ring condition on the titanium castability

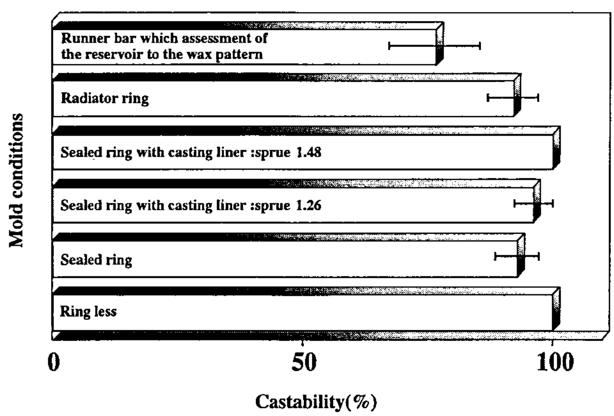

Fig. 7: Effect of mold condition on titanium castability (φ 45 mm T-INVEST C&B)

	Ring less	Sealed ring	Casting liner sprue : 1.26	Casting liner sprue : 1.48	Radiator	Runner bar which assessment of the reservoir to the wax pattern
Ring less		P<0.05	NS	NS	P<0.05	P<0.01
Sealed ring			NS	P<0.05	NS	P<0.01
Casting liner sprue : 1.26				NS	NS	P<0.01
Casting liner sprue : 1.48					P<0.05	P<0.01
Radiator						P<0.01
Runner bar which assessment of the reservoir to the wax pattern						

Fig. 8: Effect of mold condition on the titanium castability (T-INVEST C&B, F-test)

to the results under condition 1.

4. Assessment of the reservoir to the wax pattern.

A runner bar was added to the upper margin of the test wax pattern. In this situation, the castability showed significantly lower values compared to both the sealed ring casting and ringless casting ($P<0.01$, Fig. 8).

Discussion

Inoue[4] reported that a high percentage of castability was gained in cases with an all directional pressured type casting machine according to the increase of mold diameter of the T-INVEST[6,7] with high mold permeability. It was suggested that successful casting with such investment needed a large mold size.The authors of the present study examined titanium casting to regulate the optimal permeability with sealed rings and to use less investment.

1) Comparison between the sealed ring casting with different permeabilities and ring less casting.

The sealed ring was adjusted to different pressures necessary for titanium casting with almost 100% castability at every condition compared to the ring less casting with T-INVEST of high permeability of the mold. A significantly lower percentage of castability was gained in T-INVEST C&B[6,7] of low permeability molds with sealed rings at every condition ($P<0.05$, Fig. 7, 8).

These results were due to the large of heat capacity of the mold and the back pressure action in the mold of T-INVEST C&B seemed to produce negative effect regarding castability[8]. The casting machine used in this present study obtained an extremely high casting pressure and the possibility that the back pressure effect occurred was assessed at every condition.

2) Influence of the heat conductivity of the mold.

In cases with special bottom closed rings with radiation fins for dispersing heat and sealed rings, there was little difference in castability (Fig. 7, 8). It was necessary to add other considerations to analyze the problem of heat conductivity in the mold.

3) Influence of delayed gas purge and the diameter of sprue condition.

Delayed gas purge seemed to contribute to back pressure resulting in low castability.

For the purpose of exhausting the remaining gas, a casting liner was applied to the inner surface of the sealed ring. According to the report that a large sprue diameter contributed to purging remaining gas from the mold[8], casting was done with a sprue of 1.48mm.

The above results indicated that purging of remaining gas did not occur done to the liner and the large sprue size contributed to the successful casting by exhausting the gas from the mold and increasing the molten metal of the mold[5] (Fig. 7, 8).

4) Assessment of the reservoir to the wax pattern.

The manufacturer recommended adding the wax reservoir to the top of the wax pattern. The authors of the present study wished to assure the effectiveness of this reservoir. The above results indicated the negative effect to the castability ($P<0.01$, Fig. 8).

These results indicated that the reservoir in this case as a secondary runner bar provided more space for the mold chamber resulting in more gas production which acted as back pressure in casting. It was considered that adding the reservoir to the pattern was a negative factor in casting if it was wrongly attached in place and size (Fig. 7, 8). It seemed that the negative factor for titanium casting in the mold with a sealed ring was back pressure action. A high percentage of castability was gained in T-INVEST with a high permeability mold with a sealed ring with smaller amounts of investment material. A low percentage of castability was gained in T-INVEST C&B with a low permeability mold with a sealed ring. Back pressure action in the mold of T-INVEST C&B seemed to produce negative effects regarding castability. Further study should be performed on focusing problems such as negative effects on the compensatory expansion in the metal ring, range of casting liner and diameter of the casting ring.

In conclusion, we concluded that the sealed ring was effective to promote pure titanium castability with a mold of high permeability, if an all directional pressured type casting machine is used.

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抄録：純チタンの鋳造性に関する研究（第４報）通気性の低い鋳型への鋳造

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本研究の目的は全方向加圧型鋳造機を用いて，通気性の低い鋳型がチタンの鋳込率に及ぼす影響について比較検討を行うことである．埋没材は通気性の異なる２種類のリン酸塩系埋没材，T-INVEST，T-INVEST C&Bを使用し，通気性を低く設定するために鋳型の底面と側面を封鎖したseal ringを使用し

た．鋳造条件としてスプルー径は1.26，1.48mm，鋳造圧は 8 kgf/cm²，鋳型直径を25，35，45，55，65mm として比較検討を行った．その結果，通気性の高い T-INVEST に seal ring を使用すると高い鋳込率が得られた．通気性の低い T-INVEST C&B に seal ring を使用すると，危険率 5 %で鋳込率が有意に低くなる傾向を示した．T-INVEST C&B の鋳込率が低下する原因としてバックプレッシャーが考えられた．以上の結果より通気性の高い埋没材に seal ring を使用すると高い鋳込率が得られることが判明した．