Shell Materials and Casting Methods for Casting Titanium Alloys with Minimum Alpha Case
Introduction

What makes casting Titanium Different?

- High Melting point. Pure Titanium MP 1675 C (3050 F)
- Oxygen, Nitrogen, Carbon are very soluble in molten Ti
- Molten Titanium is reactive with all ceramics
- “Alpha Case”
What is Alpha Case?

Thin layer of Alpha phase Titanium on surface of a Ti casting

Hard and Brittle due mainly to high levels of Oxygen

Oxygen comes from the ceramic shell

Alpha/Beta
Ti 6-4

Alpha Case Layer
0.025” thick
Alpha Case Removal

- Machining, Sand Blasting, Chemical Milling
- Chemical Milling – Takes Time, Expensive, hazardous Chemicals
- Logical to minimize the amount of Alpha Case
Reduce Alpha Case – Foundry Operations

- Use ingot with low Oxygen, Nitrogen, Carbon
- Make sure shell is free of debris, carbon from wax, high integrity
- Use centrifuge for casting
- Minimize gating for reduced alloy cost and faster cooling
- Low shell pre-heat. Target 150 to 300 C.
- Melt alloy using Consumable Electrode or Induction
- After casting: Backfill with Argon, remove shell, fan cool

Clean Metal, Clean Shell,
Minimize time metal and shell are at high temperature
Vacuum Cold Wall Consumable Electrode Titanium Casting Furnace

(Photo and information courtesy of Retech Systems, LLC)

Standard Furnace Designs Up To:

Melt Capacity  1000 Kg (2200 lbs.)

Shell Size 1.7 m (67”) X 1.7 m (67”)

Centrifugal Casting Capable
Vacuum Cold Wall Induction Titanium Caster

(Photo and information courtesy of Retech Systems, LLC)

Metal Melting Capacity: 200 Kg (440 lbs.)
Pyrometer Measures Metal Temperature
Options: Mold Preheater, Centrifugal Casting
Minimize Alpha Case caused by Prime Layer of Shell

- Most Titanium castings are made with ZrO2 or Y2O3 Slurry.
- Prime binders are normally Silica or Zirconia
- Stuccoes used are either Alumina, Zirconia, or Yttria
- What system yields the lowest Alpha Case?
- Review a study that was done with a customer
Customer Trial – Alpha Case in Ti 6-4

- Standard test mold with added Step Wedge for Alpha Case measurement
- Buntrock Proprietary Colloidal Silica binder for prime and intermediate slurries
- Prime Flour - Yttria, CS Zirconia, 50:50 Blend
- Alumina stucco for prime and intermediate dips
- Backup Shell: Fused Silica Slurry, A-S stucco
- Shell fired to 900 C for 1 hour, cooled, cleaned
- Shell Temperature at pour: 450 C., Pour Weight 30 lbs.
- Water cooled copper crucible, Consumable Electrode, Static Pour
Alpha Case Results

Ti 6-4 Alpha Case Depth vs. Face Coat Refractory

- ZrO2
- 50:50
- Y2O3

Depth (inches x 1000)

Metal Thickness (inches)
Economics of using Yttrium Oxide

Trade off between cost of using Yttria and cost of Chemical Milling

• Compare cost of metal removed by Chemical Milling to the cost of using Yttria for the prime slurry for 1 sq. ft. of casting surface.

• Extra material cost for using Yttria

• Offset by Cost of extra Ti Alloy Dissolved during Chem Mill because of using Zirconia.
Conclusions and Recommendations

To make Titanium castings with minimum Alpha Case:

- Use low shell temperature and use small gates to avoid high metal/mold interfacial temperature. Use centrifugal casting.
- Use Yttria as a face coat ceramic rather than Zirconia.

Potential metal savings and less chemical milling may more than offset the cost premium of Yttria compared to Zirconia.
Thank you for your Attention!