

# Sintering of Titanium Alloys Studied Using Dilatometry

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## Introduction

Dilatometry has been used to make a preliminary exploration of the sintering of titanium alloys prepared using the blended-elemental powder metallurgy approach. The effects of fundamental parameters including compaction pressure and sintering temperature have been examined for “pure” titanium from different sources and for several binary alloys. Alloying elements include Mg, Si, Mn, Fe and Ni. The effect of the titanium HCP – BCC phase transformation on sintering rate has also been examined.

## Reactivity of Titanium

The reactivity of Ti imposes some experimental difficulties and restrictions on sintering conditions:

- ❖ A vacuum or inert gas atmosphere is required;
- ❖ The Ti compact must be separated from alumina components including the sample holder (eg Mo tray, disposable alumina inserts, BN powder deposit).



Titanium alloy compacts after sintering at high temperature in dilatometer; molybdenum support and alumina discs at each end adhering to compacts.

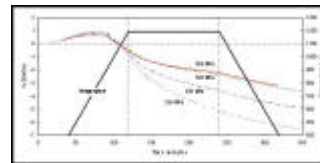
## Properties of Titanium

The following properties of Ti have a strong influence on the sintering behaviour of titanium alloys:

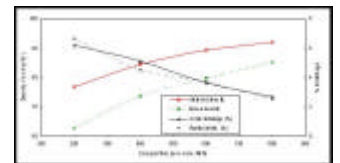
- ❖ Ability to absorb gaseous elements H, O, N (and desorb H);
- ❖ Ability to dissolve the oxide skin on particles;
- ❖ High diffusivity of Fe, Ni, Co (interstitial diffusion);
- ❖ High diffusivity in the  $\beta$  phase (high temperature BCC) compared with the  $\alpha$  phase (low temperature HCP).

## Solid-State Sintering Experiments

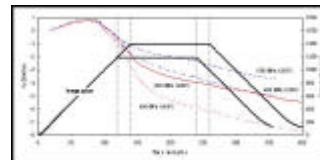
- ❖ Pure titanium powders display the expected solid-state sintering behaviour: more rapid contraction for lower compaction pressure and higher sintering temperature, reduction in rate of contraction with time at the sintering temperature;
- ❖ Thermal expansion on initial heating;
- ❖ Sintering commences once the oxide skin dissolves at about 500°C;
- ❖ More rapid sintering on transformation to the beta phase;
- ❖ Binary alloying additions have two main effects – additional expansion due to inter-diffusion and intermetallic alloy formation, followed by rapid sintering;
- ❖ Cycling through the alpha-beta transformation accelerates sintering slightly, but raising the temperature has a much greater effect;
- ❖ Almost equal contraction in the axial and radial directions.



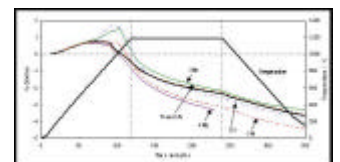
Effect of compaction pressure on sintering of pure Ti powder (1200°C 2 hr)



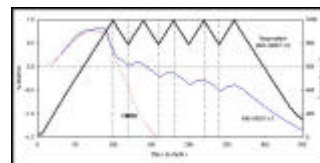
Effect of compaction pressure on density (100%Ti 1200°C 2 hr)



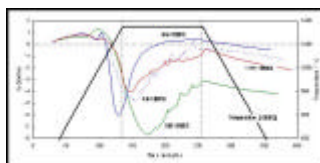
Effect of sintering temperature and compaction pressure (100%Ti, 1200° or 1400°C 2 hr)



Effect of binary alloy additions (600 MPa, 1200°C 2 hr)



Effect of cycling through the  $\alpha$ - $\beta$  phase transformation



Rapid sintering followed by generation of “giant” porosity during liquid-phase sintering of binary titanium alloys.

## Liquid-Phase Sintering (LPS) Experiments

- ❖ Liquid achieved by binary alloying additions;
- ❖ Greater danger of reaction between liquid and furnace furniture offset by lower sintering temperatures and shorter sintering times;
- ❖ Constraints on LPS due to “giant” porosity (attributed to evolution of hydrogen gas under sintering conditions; see poster by Low, Robertson and Schaffer).

## Conclusion

Some experimental difficulties in exploring the sintering behaviour of titanium alloys have been overcome, quantitative base-case data have been collected and an initial examination of liquid-phase sintering has been made.