

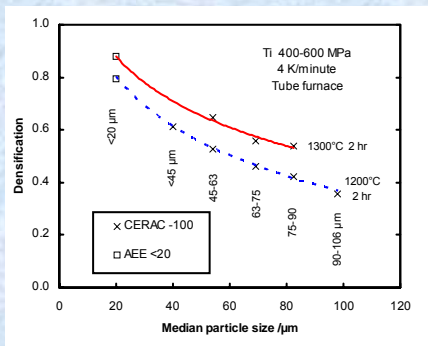
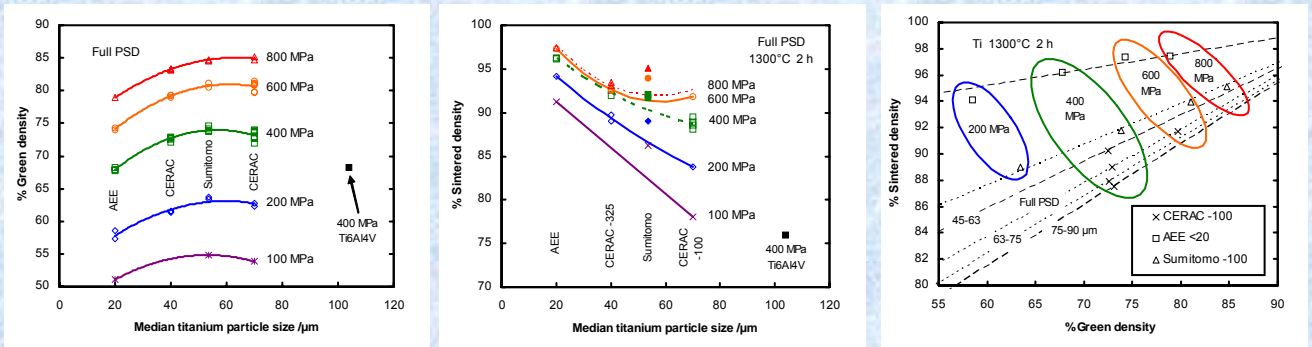
Procedure

Densification during the production of titanium-alloy net shapes using the press-and-sinter method was investigated. The quantitative effects of the particle size of titanium powders, compaction pressure and sintering time and temperature, on green and sintered density were examined. The powders and processing were as follows:

- Particle size <150 μm to <20 μm (CERAC -100 mesh, Sumitomo -100 mesh, CERAC -325 mesh, AEE <20 μm)
- Powders used in the as-received condition and after sieving to narrow size ranges
- Compaction pressure 100-800 MPa
- Sintering temperature 1100°C, 1200°C or 1300°C (under vacuum)
- Sintering time 2-6 hours.

Results

Green density was higher for coarser powders and for powders with a wider size distribution. Sintered density was higher for finer powders and for powders with a wider size distribution. Densification was little affected by the compaction pressure but increased as particle size was reduced. Densification = (Sintered density - Green density) / (Theoretical density - Green density).



Master Sintering Curve Model

An empirical model of densification based on the master sintering curve approach of Su and Johnson was developed. The influences of particle size and sintering time and temperature are combined as a single parameter, delta: an integral of the sintering rate over the sintering time. The master densification curve describes how densification increases as a function of the size-temperature-time parameter. The sintering rate follows Arrhenius kinetics, with the activation energy for densification of titanium found to be about 160 kJ/mol. This is in good agreement with the activation energy for self diffusion of titanium.

“Work of sintering” = $\int (1/T) \exp(-Q/RT) dt$ where T is temperature, t time

“Delta integral” = “Work of sintering” / (Particle size)^m

Convergence of data to a single curve indicates activation energy, Q, is 160 kJ/mol

Effect of particle size indicates the value of the exponent m is 1.9

The master densification curve varies slightly with compaction pressure

