Optimising the Properties of Net Shape HIPped Powder Ti6Al4V Samples

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1. The mild steel capsule is designed and machined
2. The powder is filled into shaped capsule designed via modelling
3. The mild steel container is evacuated and sealed
4. The encapsulated powder is HIPped: heated to 950 °C and pressed to 100 MPa.
5. The powder is fully consolidated
6. The capsule is dissolved → net shaped components!
Demonstration of net shape HIPping procedure

(Courtesy of V Samarov, LNT)
Advantages

• Mechanical properties are as good as forged
• Surface finish as good as investment casting
• Dimensional accuracy 0.1mm
• Flexibility in design
• Reduction of lead-time from design to production
• Very little machining & wastage of expensive materials
• Significant cost saving
• Net shape HIPped demonstrators of Ti6Al4V

Vinci Ti64 impeller

Oil pump housing manufactured using net shape HIPping

(courtesy of V Samarov, LNT)
Application in Aerospace

50kg aeroengine casing machined from 500kg ring-rolled ingot

HIPped from 54kg Ti64 powder. Demonstrates 90% reduction in machining
Microstructure of PREP Ti64 powder

Original β-grain boundaries
Partially HIPped samples (850°C/100MPa/2h)

Equiaxed grains forming at ppbs

Partially HIPped samples (850°C/100MPa/2h)

Powder microstructure after HT at 930°C/2h under ambient pressure
Equiaxed grains

Lath-like structure

880°C

930°C
EBSD map of β phase of sample HIPped at 1020°C

O: 2000 ppm (HIPped at 930°C)
Calculated transus is 1012°C (S Fox)
Influence of HIPping temperature on mechanical Properties of machined samples

<table>
<thead>
<tr>
<th>HIPping at</th>
<th>0.2% Proof Stress (MPa)</th>
<th>UTS (MPa)</th>
<th>El. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>880°C/100MPa/4h</td>
<td>925, 927, 931</td>
<td>989, 994, 998</td>
<td>9, 10,11</td>
</tr>
<tr>
<td>930°C/100MPa/4h</td>
<td>899, 901 904</td>
<td>970, 971, 972</td>
<td>18, 19,21</td>
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<tr>
<td>1020°C/100MPa/4h</td>
<td>836, 839, 840</td>
<td>913, 913, 913</td>
<td>10, 11, 12</td>
</tr>
<tr>
<td>Sample forged at 920~940°C [19]</td>
<td>875</td>
<td>965</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Fracture toughness, $K_Q$ (MPa.m$^{1/2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIPped Ti-6Al-4V at 930°C</td>
<td>71/74/76/77</td>
</tr>
<tr>
<td>HIPped Ti-6Al-4V at 1020°C</td>
<td>77/80</td>
</tr>
<tr>
<td>Forged Ti64</td>
<td>55</td>
</tr>
</tbody>
</table>
Influence of HIPping temperature on 4-point bending fatigue property of machined samples

![Graph showing the effect of HIPping temperature on fatigue property](image)

- HIPping at 880°C/100MPa/4h
- HIPping at 930°C/100MPa/4h
- HIPping at 1020°C/100MPa/4h

The graph illustrates the relationship between maximum applied stress (MPa) and number of cycles to failure (Nf) for different HIPping temperatures.
Influence of surface condition on fatigue limit
(4-point bending)
Improvement on surface finish and fatigue limit

As-HIPped conventional surface
Electro-polished surface
Machined surface
As-HIPped improved surface

Maximum applied stress (MPa) vs. Number of cycles to failure Nf

Steel
Ti64

Old

New
Influence of HIPping temperature on Flow Stress of partially HIPped and solid Ti64 and capsule material

![Graph showing the influence of HIPping temperature on flow stress of partially HIPped and solid Ti64 and capsule material. The graph plots temperature (°C) on the x-axis and 0.2% proof stress (MPa) on the y-axis. Three different lines represent Partially HIPped Ti6Al4V, Mild Steel A1018, and Fully HIPped Ti6Al4V. The graph includes data points at various temperatures showing the density of the partially HIPped powder.](image-url)
Summary

- A HIPping temperature of 930°C results in the best balance of properties for the conditions investigated here and these properties are comparable with those reported in forged samples.

- The fatigue limit of the as-HIPped surface is significantly improved by using a HIPping schedule which results in a much smoother as-HIPped surface than is obtained with conventional HIP schedules.

- The origin of the properties obtained in HIPped samples is the martensitic structure within the powder particles which gives rise to a fine microstructure.
For More Information

• Metallurgical and Materials Transactions A
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