Physical and Mechanical Properties of LoVAR: a new lightweight particle-reinforced Fe-36Ni alloy

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Agenda

• Background
• Initial Trials
• Process Route
• Mechanical & Physical Properties
• Summary
Background

• Because of its low thermal expansion, alloy Fe-36Ni finds extensive use in spacecraft structures that require high pointing accuracy and dimensional stability, in spite of its density (8.1g/cm³).

• For Example:
  – JWST uses 429kg
  – Kepler FPA 20kg

• However, Payload mass is a direct driver of launch cost!

• So there is a direct need to light-weight this alloy while maintaining its favourable low-expansion properties.
Initial Blending Trials
Fe-36Ni+20Si$_3$N$_4$

Necklacing of Si$_3$N$_4$ around Fe-36Ni powders

Agglomeration of Si$_3$N$_4$ to produce millimeter sized agglomerates
Process Route

Processing $\leftrightarrow$ Structure $\leftrightarrow$ Properties $\leftrightarrow$ Performance

- **Raw Materials**
  - Fe-36Ni Powder
  - Si$_3$N$_4$ Powder

- **High Energy Mixing**
  - Mixing
  - Mechanical Alloying

- **Solid-State Compaction**
  - Hot Isostatic Pressing

- **Secondary Processing**
  - Open Die Forging
Mechanically Alloyed Fe-36Ni+20Si$_3$N$_4$
Tensile Properties

![Tensile Properties Graph]

- **Stress, MPa**
- **Strain, %**

**Lines:**
- **LoVAR**
- **Invar®**
Thermal Expansion

Thermal Expansion $\Delta L/Lo$, ppm

Temperature, K

- 7A1
- 32-5 Super Invar
- LoVAR
# Secant CTE

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Room Temperature CTE (ppm/K)</th>
<th>Secant CTE 10°C to 30°C (ppm/K)</th>
<th>Secant CTE -60°C to 60°C (ppm/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoVAR</td>
<td>0.69</td>
<td>0.69</td>
<td>0.80</td>
</tr>
<tr>
<td>Super-Invar</td>
<td>0.05</td>
<td>0.06</td>
<td>0.19</td>
</tr>
<tr>
<td>Invar® (7A1)</td>
<td>1.49</td>
<td>1.49</td>
<td>1.49</td>
</tr>
</tbody>
</table>
Isothermal Dimensional Stability at 80°C
Isothermal Dimensional Stability at 80°C

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Dimensional Change (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoVAR</td>
<td>0.14</td>
</tr>
<tr>
<td>Invar® (7A1)</td>
<td>4.65</td>
</tr>
<tr>
<td>Invar® (7A3)</td>
<td>2.42</td>
</tr>
<tr>
<td>Invar® (commercial hot finished rod)</td>
<td>38.16</td>
</tr>
</tbody>
</table>

Note: LoVAR greatly reduces the isothermal time-dependent length change that has been one of the main difficulties using Invar® in optical structures.
Summary

• We have described the early stage development of a new MMC that we call LoVAR.
• It embodies a low CTE and excellent dimensional stability.
• Materion and GSFC will continue to exploit the alloy design paradigm:
  Processing $\leftrightarrow$ Structure $\leftrightarrow$ Properties $\leftrightarrow$ Performance
  To further enhance specific stiffness and stability.
• This will include a CTE matching capability.