Assessment of the structural integrity of 3-D woven carbon cloths that have undergone heating similar to Venus atmospheric entry conditions.

**Objective**

- Planetary Science Decadal Survey expresses interest in Venus
- NASA proposes Venus Interplanetary Tethered Sled (VITAL) mission
- Implement space changing technology of adaptable, deployable entry placement technologies (ADEPT)
  - Requires novel thermal protection system (TPS)
  - Low ballistic coefficient - more benign entry conditions

**Background**

- Novel 3-D woven, flexible carbon cloths
  - Tailorable weave patterns and properties
  - Interwoven weave architectures provide structural load and heat shield TPS
  - One such architecture imaged on right
  - Structural and thermal layers below

**BLAM Testing**

- Bi-axial load aerothermal mechanical (BLAM) testing
- Evaluate woven TPS under entry conditions

<table>
<thead>
<tr>
<th>Model</th>
<th>Heat Flux on Fabric (W/cm²)</th>
<th>Warp Running Load (N/cm)</th>
<th>Weft Running Load (N/cm)</th>
<th>Exposure Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>136</td>
<td>1310</td>
<td>660</td>
<td>35</td>
</tr>
<tr>
<td>B2</td>
<td>97</td>
<td>660</td>
<td>330</td>
<td>135</td>
</tr>
<tr>
<td>B3</td>
<td>97</td>
<td>1310</td>
<td>660</td>
<td>139</td>
</tr>
</tbody>
</table>

**Mechanical Testing**

- Instron 5569, ε = 1mm/min
- Fabric and yarns, pre and post aerothermal exposure

**Fabric Test**

- Post-exposure strength exceeds flight requirement
- Brittle failures in post-exposure fabrics
- Reduction in mechanical properties correlated with exposure duration

**Results**

- Fabric testing provides design guidelines for future woven TPS

**Yarn Test**

- Imaged above: Woven fabric at 4 minutes, weave elongation
- Lower image: Failed yarn, bundle loosening

**Observations**

- Data indicates that aerothermal heating reduces mechanical strength
- Arcjet exposure appears to cause sample embrittlement
- Mechanical testing provides design guidelines for future woven TPS

**Conclusion**

- Investigate the causes of embrittlement and reduction in load bearing capacity due to aerothermal heating
- Isolate effects of oxidation and thermal exposure on mechanical performance
- Additional fabric testing to statistically verify mechanical property reductions

**Forward Work**

- \( \Delta \) Requires novel thermal protection system (TPS)
- \( \Delta \) Low ballistic coefficient - more benign entry conditions

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