LOW VELOCITY IMPACT PERFORMANCE OF AEROGEL-FILLED SANDWICH COMPOSITES

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Key words: Aerogel, Sandwich composites, Impact energy, Composites manufacturing.

ABSTRACT

Aerogel is an extremely lightweight material with amazing properties. Silica aerogels, due to their highly porous form are extremely lightweight. Their low density, 0.003 - 0.1 g/cm³, and low thermal conductivity, 0.013 - 0.04 W/mK, present opportunities for applications in thermal insulation fields. However, inherent brittleness of silica aerogel imposes challenges in handling, structural integrity and application. For better utilization of the material, granular silica aerogels were proposed to be used as fillers, as pourable and formable insulation, in carbon or glass composite sandwich structures. These aerogel-filled sandwich composites then can be used in providing shielding against undesired heat gain or unwanted heat loss. The possible applications of these composites would include aircraft cabins, heat shelters and building partitions provided they possess necessary strength, stiffness and impact resistance.

One of the primary concerns in the use of aerogel-filled sandwich composites is the damages induced by low velocity impacts (LVI) that can occur in service. Impact induced damage can cause severe degradation of the strength and stiffness of the sandwich structure. Therefore, the LVI response of aerogel-filled sandwich structures needed to be addressed.

This paper presents the development work of co-cured aerogel-filled sandwich structures and the studies on their impact resistance. Woven fabric prepregs of carbon and glass, due to their high specific strength and stiffness, were used for fabricating various grid forms wherein the granular aerogel was filled to impart thermal insulating properties. The composite walls of the grid added strength to the structure and protected aerogels of any loading. The same prepregs were used for the face-sheets to the aerogel-filled sandwich core. Two layers of carbon prepreg and four layers of glass prepreg were used for the face-sheets of the respective specimens. Samples of 100x100x15mm in size with aerogel compartments of 50x50mm square dimensions were fabricated on which LVI tests were conducted for studying their impact response and compare it with the conventional honeycomb sandwich composites. Impact tests were carried out with the help of a drop weight impact test machine (DYNATUP model 8250). The drop height of the impactor was fixed at 1m. After factoring energy losses,
The velocity of the impactor was measured to be constant at $3.16 \pm 0.1$ m/s with the constant kinetic energy of $13.65 \pm 0.5$ J at impact. The LVI test results were compared with the similar tests performed on AeroWeb honeycomb sandwich samples. Note that impact response was studied at different points around the aerogel compartment as shown in Table 1.

<table>
<thead>
<tr>
<th>Test location of aerogel compartment</th>
<th>Sample type</th>
<th>Time to max load (ms)</th>
<th>Total absorbed energy (J)</th>
<th>Maximum load (kN)</th>
<th>Energy to max load (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the centre</td>
<td>Honey Comb</td>
<td>1.11</td>
<td>10.45</td>
<td>0.92</td>
<td>1.70</td>
</tr>
<tr>
<td>Corner of compartment</td>
<td>Type A</td>
<td>3.13</td>
<td>12.10</td>
<td>1.09</td>
<td>5.92</td>
</tr>
<tr>
<td>Centre of compartment</td>
<td>Type B</td>
<td>7.78</td>
<td>6.81</td>
<td>0.84</td>
<td>5.74</td>
</tr>
<tr>
<td>Side of compartment</td>
<td>Type C</td>
<td>8.66</td>
<td>11.17</td>
<td>1.20</td>
<td>8.93</td>
</tr>
</tbody>
</table>

The experimental results revealed that single step co-curing process allowed faster and less complex fabrication. The impact studies showed that the aerogel-filled sandwich composites were capable of withstanding impact loads along the walls of the aerogel compartments. The centre of the compartment did not receive impact load as well as the sides of the compartments; however, they exhibited a much higher energy at the maximum load.

The observed penetration failures were primarily due to matrix cracking, fibre breakage and crushing of the core. The damage propagation was along the fibre orientations of the face-sheets giving a star-shaped appearance due to 0/90 patterns.

On the whole, the aerogel-filled sandwich composites were comparable (and slightly better, in some cases) to the honeycomb sandwich composites in their impact response.