Processing of Sandwich Structures

By
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Sequence of Presentation

- Sandwich Construction
- Why Sandwich Structure?
- Core materials and their comparisons
- Manufacturing of sandwich structures
  - Prepreg based processing
  - Out of autoclave processing
  - Liquid resin Infusion of Sandwich structures
  - Quality check
Sandwich Construction

- Thin face-sheets (Carbon, Glass, Kevlar etc.)
- Thick core materials (Foam, honeycomb, balsa etc.)
- Joined with adhesive (liquid resin, adhesive film, foaming adhesives etc.)
Sandwich panels are a very efficient way of providing high bending stiffness at low weight. The stiff, strong facing skins carry the bending loads, while the core resists shear loads. The principle is the same as a traditional ‘I’ beam.
Why Sandwich Construction?

Bending stiffness is increased by making beams or panel thicker - with sandwich construction this can be achieved with very little increase in weight:

<table>
<thead>
<tr>
<th></th>
<th>Solid Material</th>
<th>Core Thickness t</th>
<th>Core Thickness 3t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness</td>
<td>1.0</td>
<td>7.0</td>
<td>37.0</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>1.0</td>
<td>3.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Weight</td>
<td>1.0</td>
<td>1.03</td>
<td>1.06</td>
</tr>
</tbody>
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Sandwich Construction

The stiff, strong facing skins carry the bending loads, while the core resists shear loads.

Total deflection = bending + shear
Bending depends on the skin properties; shear depends on the core
# Sandwich Construction

<table>
<thead>
<tr>
<th>Material</th>
<th>Property</th>
<th>Honeycomb Advantages</th>
</tr>
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<tbody>
<tr>
<td>Foam includes</td>
<td>Relatively low crush strength and stiffness</td>
<td>Excellent crush strength and stiffness</td>
</tr>
<tr>
<td>– polyvinyl chloride (PVC)</td>
<td>Increasing stress with increasing strain</td>
<td>Constant crush strength</td>
</tr>
<tr>
<td>– polymethacrylimide</td>
<td>Friable</td>
<td>Structural integrity</td>
</tr>
<tr>
<td>– polyurethane</td>
<td>Limited strength</td>
<td>Exceptionally high strengths available</td>
</tr>
<tr>
<td>– polystyrene</td>
<td>Fatigue</td>
<td>High fatigue resistance</td>
</tr>
<tr>
<td>– phenolic</td>
<td>Cannot be formed around curvatures</td>
<td>OX-Core and Flex-Core cell configurations for curvatures</td>
</tr>
<tr>
<td>– polyethersulfone (PES)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood-based includes</td>
<td>Very heavy density</td>
<td>Excellent strength-to-weight ratio</td>
</tr>
<tr>
<td>– plywood</td>
<td>Subject to moisture degradation</td>
<td>Excellent moisture resistance</td>
</tr>
<tr>
<td>– balsa</td>
<td>Flammable</td>
<td>Self-extinguishing, low smoke versions available</td>
</tr>
<tr>
<td>– particleboard</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*List compiled by company (Hexcel) which sells honeycomb!*
Honeycomb is available in polymer, carbon, aramid and GRP. The two commonest types in aerospace applications are based on aluminum and Nomex (aramid fiber-paper impregnated with phenolic resin).

Cells are usually hexagonal: but ‘over-expanded’ core is also used to give extra formability.
Sandwich Construction

Core properties depend on density and cell size. They also depend on direction - the core is much stronger and stiffer in the ‘ribbon’ or ‘L’ direction:
Aluminum generally has superior properties to Nomex honeycomb.
**Aluminum Honeycomb**
- relatively low cost
- best for energy absorption
- greatest strength/weight
- thinnest cell walls
- smooth cell walls
- conductive heat transfer
- electrical shielding
- machinability

**Aramid Fiber (Nomex) Honeycomb**
- flammability/fire retardance
- large selection of cell sizes, densities, and strengths
- formability and parts-making experience
- insulative
- low dielectric properties
Manufacturing of Sandwich Structure

Prepreg based Sandwich Structures

Diagram:
- Sandwich Construction Processing Methods
  - Autoclave
  - Vacuum Bag
  - Press
Prepreg based Sandwich Structures - Heated Press

- Heated Press, generally used for the production of flat board or simple preformed panels.

  Ideally the panels should be assembled ready for curing as a single shot process.

- This method is suitable for metallic and prepreg (pre-impregnated) facing skins.

- Alternatively prepreg facing skin materials may be pre-cured by using a press, and subsequently bonding with a film adhesive layer.
Manufacturing of Sandwich Structure

Prepreg based Sandwich Structures- Vacuum Bagging

• Vacuum Bag Processing, used for curved and complex form panels.

• The component should be assembled for cure as a single shot process, the necessary consolidation is obtained using a vacuum. This can be cured in an oven, and additional pressure can be applied if an autoclave is used.

• This method is suitable for items with prepreg or preformed composite or metallic facing skins. When flexible or formed honeycomb core and film adhesives are used complex items may be produced.
Manufacturing of Sandwich Structure

Prepreg based Sandwich Structures- Vacuum Bagging and autoclave cure
Autoclave Processing

• Mature and standardized method for composites manufacturing
• Controlled thermal Program, high pressure environment
• High fiber volume fraction, low void content hence, maximum strength
• Largest autoclave size (30’ dia x 76’ length) built for Boeing 787 fuselage
• Expected to be 20% more fuel efficient than Al jets with multiple other attributes
Out of autoclave Processing?

- Aerospace Programme timescales Shortening
- Production rates increase as the time to reach these rates decreases
- Capital expenditure, infrastructure requirements and commissioning time makes autoclave processing increasingly undesirable
- Autoclave running cost comparatively high
- Development of alternative processes and prepregs are in progress
Vacuum bagging

- Inconsistent fiber/resin ratio: hence inconsistent product quality
- Very high void content: Lower interlaminar properties
- High wastage of resins
- Limited Set up Time (in case of gelification, part could be discarded)
- Not a very clean process-Workers are exposed to resin throughout the process
Better Option: Vacuum Infusion Process

Vacuum Infusion - The Equipment and Process of Resin Infusion

- The Vacuum Infusion Process (VIP) is a technique that uses vacuum pressure to drive resin into a laminate.
- Materials are laid dry into the mold and the vacuum is applied before resin is introduced.
- Once a complete vacuum is achieved, resin is literally sucked into the laminate via carefully placed tubing. This process is aided by an assortment of supplies and materials.
Liquid Resin Infusion of Sandwich structures
Quality Checks
Quality Checks
Quality Checks
Sandwich constructions made with other core materials (balsa, foam, etc) have a large surface area available for bonding the skins.

In honeycomb core, we rely on a small fillet of adhesive at the edge of the cell walls:

The fillet is crucial to the performance of the sandwich, yet it is very dependent on manufacturing factors (resin viscosity, temperature, vacuum, etc).
Thanks