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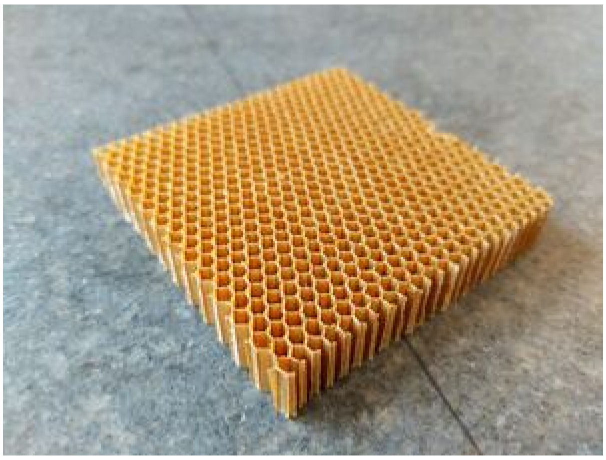
Honeycomb	
	
Nomex honeycomb with hexagon cell	
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Introduction[edit | edit source]

Honeycomb is an array of open cells made from thin sheets of material attached to each other. Honeycomb and composite sandwich panels can have extremely high performance and are commonly used in aerospace control surfaces, engine nacelles, interior shelving, floor panels and other light weight high stiffness applications. Honeycomb can be made from a wide range of metallic (aluminum, stainless steel) or nonmetallic (aramid (Nomex), polypropylene, polycarbonate, thermoplastic etc.) materials. Other applications of honeycomb include fluid smoothing (aerodynamic), architecture, energy absorbing structures and EMI/RFI shielding.

Scope[edit | edit source]

This page focuses on honeycomb core material. Honeycomb convention/terminologies, manufacturing processes, various types and cell configurations are discussed. Major suppliers of honeycomb materials are included.

Significance[edit | edit source]

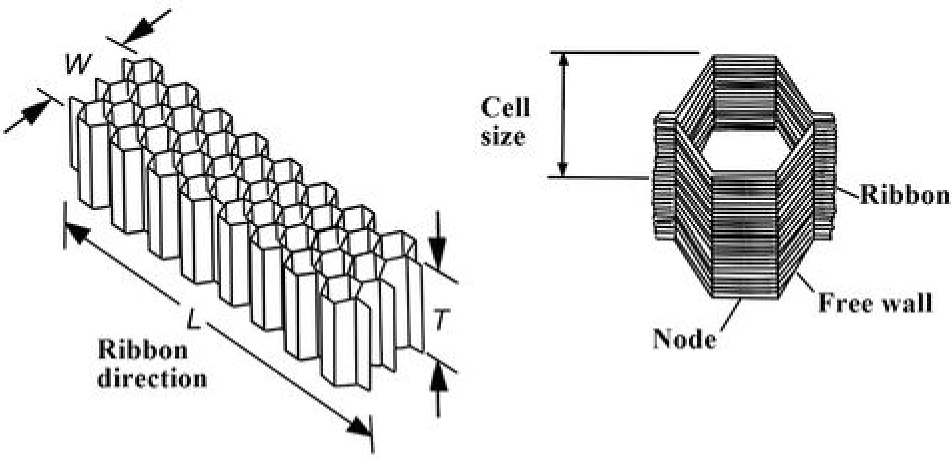
Compared to other core materials such as wood or foam, honeycomb is more mass efficient as it provides a better combination of mechanical properties and light weight. Honeycomb as a core material should be considered whenever there is a skin buckling problem. Honeycomb combined with composite laminate skins can provide extremely high strength/stiffness parts with low weight.

Along with high fatigue resistance honeycomb sandwich structures are ideal for many aerospace applications.

Honeycomb terminology[edit | edit source]

Some common terminology for honeycomb is listed below (please refer to the image). These conventions are often used during honeycomb and sandwich panel design and manufacturing:

- Honeycomb density - typically in pounds per cubic foot (pcf) or kilogram per cubic meter (kg/m^3)
- Cell - a constituent unit of the honeycomb, honeycomb cells can have different configurations
- Ribbon - the flat(continuous) sheet material of the honeycomb, also known as web
- Node - the bonded portion of two adjacent ribbons
- Free wall - the unbonded portion of a cell
- Cell size - dimension between two nodes after expansion. (See honeycomb manufacturing process for details about expansion)
- L direction - the ribbon direction
- W direction - the direction in which the core is expanded, perpendicular to the L direction
- T direction - the direction parallel with the cell openings



Overexpanded Nomex honeycomb (rectangular cell)

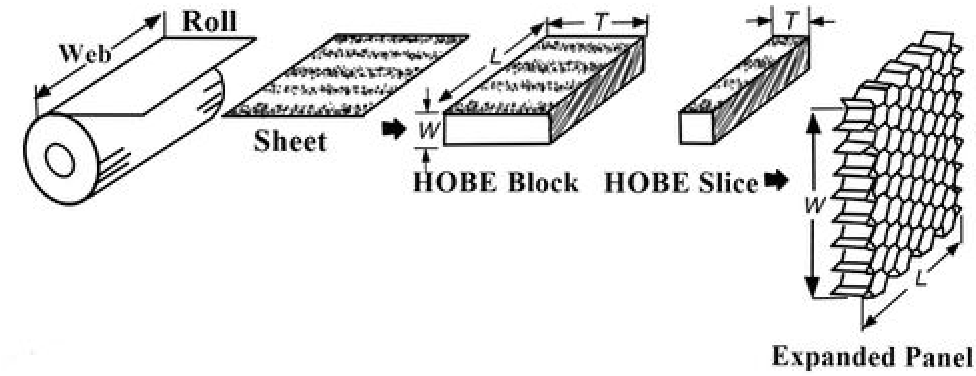
Honeycomb manufacturing process[edit | edit source]

95% of honeycomb is made using adhesive bonding where lines of adhesive are printed at the nodes on the sheet material and stacked together. Other manufacturing methods include resistance welding, brazing, diffusion bonding, and thermal fusion; which are more expensive and used only for honeycombs that are seeing extreme conditions. For example, stainless steel and Inconel honeycomb have their nodes brazed or spot welded, and can be used up to around 700 °C (1300 °F). For some thermoplastic materials, the nodes are partially melted by heat, pressed together and solidify when cooled, no adhesives are required.[1]

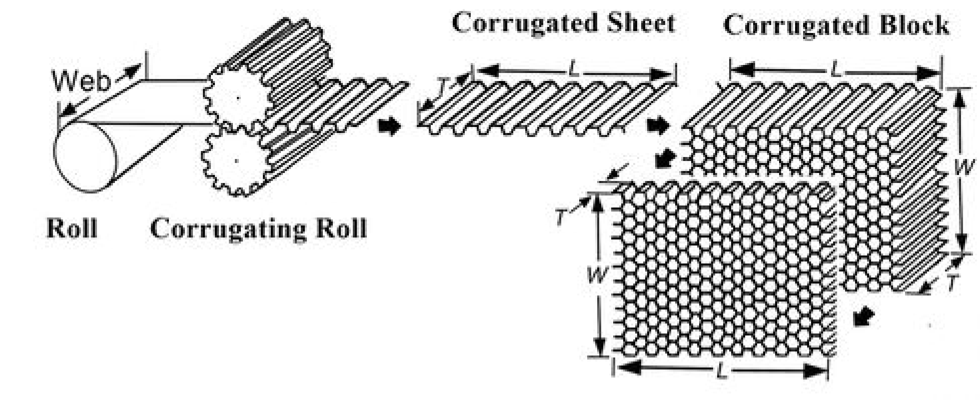
There are two techniques for forming honeycombs from sheet materials: the expansion process and the corrugation process.

In the expansion process, flat sheets are stacked with adhesive printed in-between, forming the unexpanded block (honeycomb before expansion, HOBE). The adhesive is cured at elevated temperature and pressure (about 300 psi) in a press. Then the HOBE is cut to the desired thickness and expanded. When a metallic honeycomb is made by the expansion process, the sheet deform plastically at the nodes and maintaining the expanded geometry. When a non-metallic honeycomb material (such as paper, Nomex for example) is expanded, the honeycomb does not retain its shape and a rack is used to hold the honeycomb. The honeycomb is then dipped in liquid resin and cured in an oven to lock in the shape. The liquid resin is typically phenolic or polyimide and the dipping process is repeated (anywhere from 2 to 30 times) until the desired honeycomb density is reached.

In the corrugation process, the flat sheets first pass trough a series of corrugating rollers, then the corrugated sheets are bonded at the nodes with adhesive and cured in an oven. This process is more applicable to core materials that can sustain its shape in corrugated sheet from (e.g. metals and some non-metallic materials, not paper). Since corrugated sheets are being stacked, only light pressure can be applied during the bonding and curing process. This results in much thicker adhesives (10% of total honeycomb weight) compared to the expansion process (around 1% of total honeycomb weight).[1]



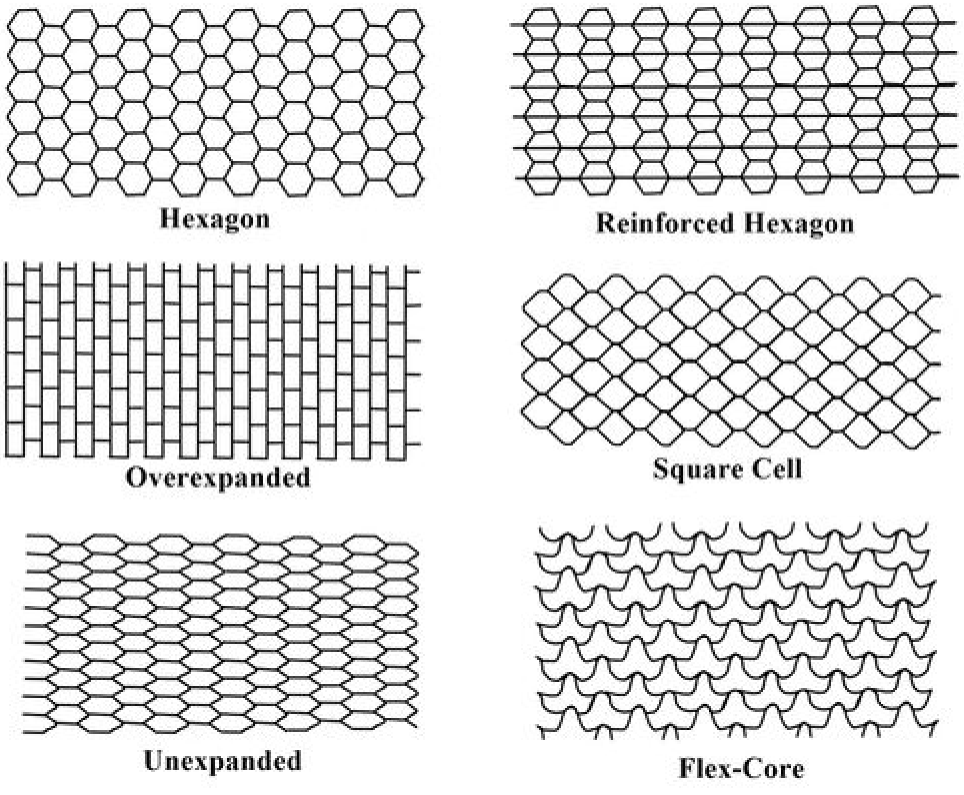
Honeycomb expansion method



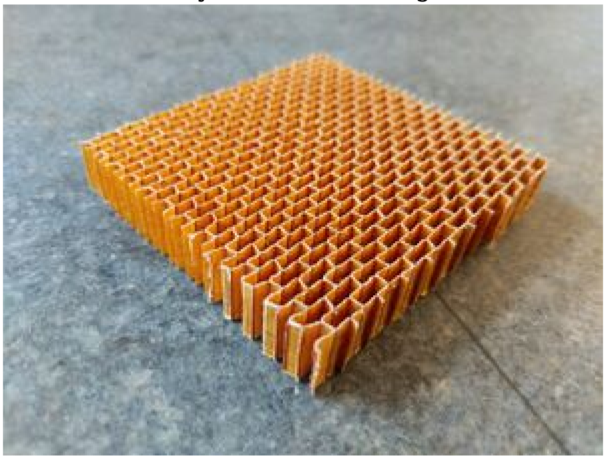
Honeycomb corrugation method

Honeycomb cell configuration[edit | edit source]

Different cell shapes/configurations require variation in the manufacturing process and can affect the mechanical properties and handling characteristics of the honeycomb. The most common cell shapes are hexagon, square and flex-core. Different configurations include overexpanded, underexpanded or reinforced.



Different honeycomb cell configurations



Overexpanded nomex honeycomb
(rectangular cell)

The hexagon honeycomb cell resembles the natural bee hive and is the most common cell shape. The over-expanded core is the standard hexagon core but overexpanded, resulting in rectangular cell shape. The overexpanded core has lower bending stiffness in the L direction compared to the standard hexagon cell, making it easier to conform to curvatures in the L direction. The shear strength and modulus in the L direction is lower than in the W direction, which is higher compared to standard hexagon cell shape.

Metallic honeycomb[edit | edit source]

The most common metallic honeycomb materials are aluminum, stainless steel and titanium. Stainless steel is very commonly produced using the corrugation process. Copper and lead has also been made into honeycomb although much less common. The density of the metallic honeycomb core is mainly affected by foil thickness and cell configuration.

Aluminum honeycombs can be made by both expansion and corrugation. Corrugated aluminum cores are usually more expensive because it is more time consuming to produce. The corrugation method is used because it is impossible to expand the HOBE above 12 pcf (192 kg/m^3). Corrugated aluminum cores density can range from 12 to 55 pcf (192-880 kg/m^3) As a rule of thumb, expanded cores should be used whenever possible.[1]

Non-metallic Honeycomb[edit | edit source]

Once expanded, non-metallic cores are dipped in resin to fix the geometry[2]. Various thermoset and thermoplastic resins can be used depending on the application. Phenolic resin is very commonly used. Polyimide is used for high temperature applications. Thermoplastic can be used for increasing toughness. Typical resin content by weight is around 40% to 60%.

Fabric honeycombs can have the fabric oriented in 0°-90° direction (straight weave) or in ±45° direction (bias weave). The shear moduli of bias weave honeycomb can be three times higher than that of the straight weave honeycomb. For example, bias weave honeycomb made from carbon fiber (very costly) can be made into sandwich structures with extremely high stiffness and shear properties for some space applications. Because the constituent material is woven fabrics instead of sheets, fabric honeycombs require a different corrugation process to manufacture.

Thermoplastic honeycombs can be made by expansion, corrugation or extrusion. In either expansion or corrugation, the nodes are heat fused together, eliminating the use of adhesives. Whereas with extrusion, the honeycomb is extruded and sliced to the desired thickness. Thermoplastic honeycombs can be very tough but generally have lower strength compared to the thermoset counterparts.

Suppliers[edit | edit source]

Some major manufacturers and distributors of honeycomb include:

- Toray
- Hexel
- Dupont
- Corex honeycomb
- HoneyCommCore, LLC.
- Plascore
- The Gill corporation
- RAYPLEX
- MachineTek LLC
- Rock West Composites

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References

1. ↑ [1.0] [1.1] [1.2] [Ref] Bitzer, Tom (1997). *Honeycomb Technology Materials, Design, Manufacturing, Applications and Testing*. 1997 Springer Science+Business Media Dordrecht. doi:10.1007/978-94-011-5856-5. ISBN 978-94-011-5856-5.
2. ↑ [Ref] Campbell, F.C. (2004). *Manufacturing Processes for Advanced Composites*. Elsevier. doi:10.1016/B978-1-85617-415-2.X5000-X. ISBN 9781856174152.

About **Help**

Engineered materials (designed to have specific properties) made from two or more constituent materials with different physical or chemical properties. The constituents remain separate and distinct on a macroscopic level within the finished structure.

A class of polymer, some common examples include polypropylene and polyethylene.

They soften and melt upon heating (i.e. potentially recyclable), high viscosity when melted, therefore difficult to saturate fibres. Usually needs a lot of pressure and heat to process.

A joining process where a polymeric material (the adhesive) joins two separate structural pieces called adherends. Adhesive bonding is used instead of, or in parallel with mechanical means of joining such as riveting or bolting.

For polymer matrix composites (PMCs), resin refers to the matrix; the continuous material phase that binds the reinforcement together, maintains shape, and transfers load. Resins are divided into two main groups: thermosets and thermoplastics.

Thermosets are a class of polymer that undergo polymerization and crosslinking during curing with the aid of a hardening agent and heating or promoter. Initially they behave like a viscous fluid. During curing, they change from viscous fluid to rubbery gel (viscoelastic material) and finally glassy solid.

If heated after curing, initially they become soft and rubbery at high temperatures. If further heated, they do not melt but decompose (burn)

Comes in two parts: part A (resin) and B (hardener). When mixed, curing reaction starts and is not reversible.

Examples include epoxy or polyester.