

A328

Foam



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Introduction[[edit](#) | [edit source](#)]

Foam as a core material was developed to be used as a lightweight alternative to natural core materials (various woods). Compared to wood cores, foam in general has less local density variations and less moisture absorption. Another advantage of foam compared to wood or honeycomb cores is the potential to be thermoformed into complex geometry while maintaining relatively uniform properties. While wood or honeycomb can be formed or machined into shape, the process may be more complicated and expensive. Typically, the properties of foam core are not as good as [honeycombs](#) but foam is more economical. It is widely used in marine, wind energy and transportation applications.

Almost all polymer (uncross-linked thermoplastic and cross-linked thermoset) can be made into a foam with proper foaming or blowing agents. Thermoset generally has better mechanical properties while thermoplastic foams are more formable. Thermoset foams can also be lightly cross-linked to achieve higher formability. Foam density is usually measured in pounds per cubic foot (pcf) or kilogram per cubic meter (kg/m^3). Foam core density can range from 2 to 40 pcf.^[1]

Scope[[edit](#) | [edit source](#)]

Although metallic and glass foam core exist, this page focuses on polymer foam core materials. The difference between open-cell and closed-cell foam is discussed, then various manufacturing processes for foam and common foam core materials are covered.

Significance[[edit](#) | [edit source](#)]

As with other core materials, the purpose of the foam is to increase the thickness (thus bending stiffness) of the sandwich structures without a significant increase in weight. Other beneficial functions such as acoustic or heat insulation and damping may also be achieved thanks to the properties specific to a type of foam. Because almost any polymer can be made into foam, compounding with the various manufacturing techniques, foams are available in a wide variety of options. Uncross-linked thermoplastic vs cross-linked thermoset, cell structure (opened-cell vs closed-cell), density, rigid/flexible/rubbery among numerous other properties^[2]. Designers should understand the implications of these foam parameters when selecting foams to fulfill the functions and requirements of the to-be-designed product.

Manufacturing of foam cores[[edit](#) | [edit source](#)]

Foam can come in either two-part liquids for foam-in-place applications or pre-expanded block form. The two-part liquids are mixed and poured into a mould where the mixture expands into the desired shape whereas the pre-expanded blocks can be bonded together, then formed or machined into shape. Foam can also come in flexible sheet form where the small blocks are held by a fabric scrim backing, similar to flexible balsa sheets.



Flexible foam core with scrim fabric backing)

Polymer foam is produced by mixing the liquid polymer with the proper foaming or blowing agents. The mixture is poured into a mould and cured with heat and pressure. The resulting rubbery conglomeration is then heated again with a second mould in an expansion chamber (with hot water or steam). During the second heating cycle, the gas expansion pressure is controlled and the blowing agents are activated. The agents can function either physically or chemically. Physical blowing agents are gases mixed into the foam material that expand when heated. While chemical blowing agents depend on the agent decomposition during heating which produce off gases (usually nitrogen or CO₂).^[3]

Foam core structures[\[edit\]](#) | [edit source](#)

The cells of the foam core can be interconnected (open-cell) or closed and discrete (closed-cell). A core can have both open-cells and closed-cells with a percentage of each. Closed-cell foams generally have higher density and better mechanical properties than open-cell foams. Hence most foam cores used for structural applications are closed-cell. In general, the higher the foam density the higher percentage of closed cells.^[4]

Open-cell foam is made with blowing agents (for example, sodium bicarbonate) that reacts with the polymer during the second heating cycle. The blowing agent "eats through" the polymer and creates an interconnected network of gas pockets. Closed-cell foams on the other hand are made with blowing agents that does not degrade the foam's cell structure, leaving gas pockets discrete.^[4] Some characteristics of open and closed cell foams are listed below:

Open-cell foams are:

- softer and more springy (returns to original shape once deformed)
- breathable, allows air or other fluids to pass through
- good for sound absorption/insulation

Closed-cell foams are:

- rigid
- less permeable

Common polymer foam materials[\[edit\]](#) | [edit source](#)

Polyurethane[\[edit\]](#) | [edit source](#)

Polyurethane (PU) foam is available in uncross-linked thermoplastic and cross-linked thermoset form with varying percentage of closed cells.^[1] Mix-and-pour/foam-in-place two part thermoset polyurethane is also common for insulation applications. Depending on the polymer formulation, some PU foam can be used up to 275 °F and 350 °F, enabling them to be cured with high temperature [pre-pregs](#) in [ovens](#) and [autoclaves](#).^[5] PU foam typically has moderate mechanical properties and are prone to core-to-face sheet delaminate with age. PU foam can be easily machined to the desired shape. Hot wire cutting PU foam should be avoided since toxic fumes can be generated.^[1]

Polyvinyl chloride (PVC)[\[edit\]](#) | [edit source](#)

Polyvinyl chloride (PVC) is the most widely used foam core materials for sandwich panels^[3]. PVC foam are also available in uncross-linked thermoplastic and cross-linked thermoset form with differences in polymer formulation. Both the thermoset and thermoplastic PVC can be thermoformed and exhibit good fatigue performance. Density of PVC foams can range from 1.8 to 26 pcf^[1]. Differences in characteristics of each are listed as follows:

Cross-linked thermoset PVC:

- Better mechanical properties than the thermoplastic version
- Better heat resistance (can be used up to 135°C/275°F)
- More brittle and more difficult to thermoform

- Better chemical resistance. Resistant to styrene, allowing cross-linked thermoset PVC to be used with polyester and vinyl ester resins

Uncross-linked thermoplastic PVC:

- Lower mechanical properties
- More elastic, higher deflection/deformation before failure
- Tougher and more damage resistant
- Easier to thermoform
- Poorer thermal and chemical resistance

Polymethylmethacrylimide (PMIs)[\[edit\]](#) | [edit source](#)

Polymethylmethacrylimides (PMIs) are lightly cross-linked closed-cell foams that have very good mechanical properties and can be processed at very high temperatures (200°C/400°F). Density of PMI foams can range from 2 to 18.7 pcf^[1]. PMI foams can also be thermoformed. Because of this, PMIs are typically expensive and only used for high performance applications such as [ovens](#) or [autoclaves](#) cured sandwich panels with [pre-pregs](#)^{[1][3]}

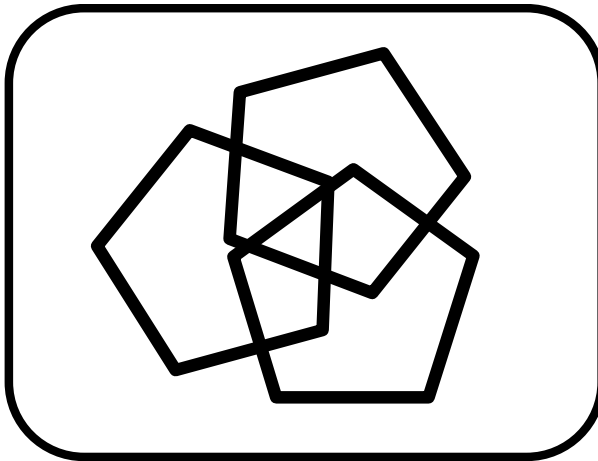
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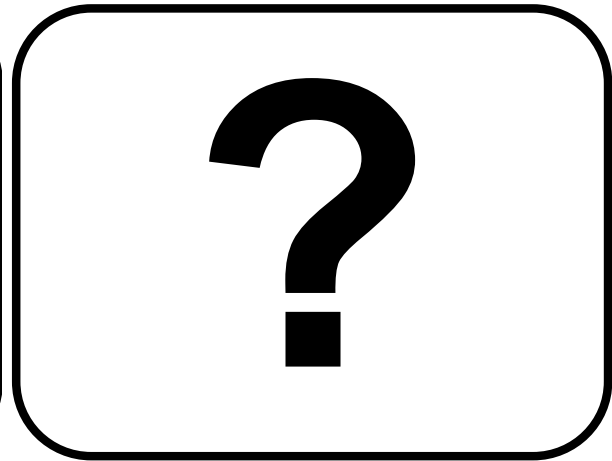
References

- ↑ ^{1.0} ^{1.1} ^{1.2} ^{1.3} ^{1.4} ^{1.5} [Ref] Campbell, F.C. (2004). *Manufacturing Processes for Advanced*

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 3. [↑ ^{3.0} ^{3.1} ^{3.2} \[Ref\]](#) CompositesWorld (2003). "[Getting To The Core Of Composite Laminates](#)".
 4. [↑ ^{4.0} ^{4.1} \[Ref\]](#) *Open Cell & Closed Cell Foams Keys to Making the Right Selection*, JBC Technologies, 2019
 5. [↑ \[Ref\]](#) "[How to Choose Composite Core Materials for Your Application](#)". AZO Materials. 2020.



About



Help

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.

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.