Sandwich Core Materials & Technologies – Part I

Dr. Scott W. Beckwith, SAMPE International Technical Director
and President, BTG Composites Inc., Salt Lake City, UT
Email: swbeckwith@aol.com

Sandwich structures represent a key component of composites structural design technology. They provide the structural efficiency of very lightweight materials "sandwiched" between higher performance (strength, stiffness) composite laminates in order to carry tension, compression and shear loads imposed upon the resultant structure. The core materials selected for the center of the sandwich structure come in a variety of material types, forms and properties (both mechanical and physical). The end-use application very often dictates what material is best for the resultant structural application.

This particular "tech tidbits note" will be offered in two parts since core materials tend to focus on wood/foam cores and honeycomb cores as distinct families. Core materials actually fall into several categories: balsa wood, foams, corrugated and honeycomb. Part I will concentrate on balsa wood and foam cores while Part II will discuss corrugated and honeycomb cores. The primary properties of interest in core materials are typically:

- Density – lightweight is the desired goal of these materials
- Shear modulus and shear strength – the core carries the bulk of the shear loads (hence high strength and stiffness values are very important to structural performance)
- Compression stiffness and strength – core materials must carry the loads perpendicular to the laminate face sheets
- Thermal properties – often the core must act as an insulator and heat transfer must be kept to a minimum

End-use applications also strongly dictate various material properties of the core materials that are equally important to structural design aspects such as those noted above. For example, space structures and satellite components very often require a much higher temperature capability (say 350F/177C or higher). These same structures also typically require that the core materials (a) absorb very low moisture content and (b) exhibit very low off-gassing of any volatile or residual ingredients within the foam. The primary reasons are that these ingredients often result in internal cracking or porosity as well as "fog up" or "contaminate" critical components (e.g. space mirrors, telescope lenses, optical equipment, electronic circuitry, etc.).

Core material families exhibit a wide range of material costs, advantages and disadvantages across the applications spectrum. Table 2 explores a few of these factors for each family given above.

References

1. *The Handbook of Sandwich Construction*, Edited by D. Zenkert, EMAS/Engineering Materials Advisory Services Ltd., 1997, ISBN 0-947-81796-4.
2. *Handbook of Composites*, Second Edition, Edited by S.T. Peters, Chapman & Hall, 1998, ISBN 0-412-54020-7.

Table 1. Balsa wood and some commonly used foam core material systems.

Core Material Family	***Typical Density Range, kg/m^3 (lb/ft^3)***	***Shear Strength, MPa (psi)***	***Shear Modulus, MPa (ksi)***	***Compression Strength, MPa (psi)***	***Maximum Service Temperature, °C (°F)***
Balsa Wood (closed end grain)	96-250 (6-16)	1.85-4.94 (270-720)	108-312 (15.7-45.3)	6.5-26.6 (945-3860)	165 (325)
Polyurethane Foam (PUR)	21-400 (1.5-25)	0.15-3.1 (20-450)	1.55-104 (0.23-15.0)	0.2-0.35 (29-50)	135 (275)
Polystyrene Foam (PS)	30-60 (2-4)	0.25-0.60 (36-90)	4.5-20 (0.65-2.9)	0.3-0.9 (44-130)	100 (212)
Polyvinylchloride Foam (PVC)	30-400 (2-25)	0.35-4.5 (50-655)	8.3-108 (1.2-15.7)	0.3-5.8 (44-840)	55-120 (130-250)
Polymethacrylimide Foam (PMI)	30-300 (2-20)	0.8-7.5 (115-1090)	19-290 (2.8-42.1)	0.8-16 (116-2325)	140 (285)
Polyetherimide Foam (PEI)	60-110 (4-7)	0.8-1.4 (120-200)	18-30 (2.6-4.4)	0.7-1.4 (100-200)	180-190 (355-375)
Styrene-acrylonitrile Copolymer Foam (SAN)	48-160 (3-10)	1.3-3.5 (180-510)	13.8-41.4 (2.0-6.0)	0.35-10.3 (50-1500)	135 (275)
Epoxy Foam	80-320 (5-20)	0.45-5.2 (65-755)		0.62-7.4 (90-1075)	177 (350)
Phenolic Foam	5-160 (0.5-10)	0.01-1.45 (1.4-210)		0.014-2.07 (2.0-300)	145-200 (300-390)
Carbon/Graphite Foams	30-560 (2-35)	0.05-3.9 (7.3-566)		0.2-60 (29-8700)	~2500 (~4530)

Note: The various properties noted above are heavily dependent upon the foam density with an increase being proportional to degree of compaction, cell density, and use temperature

Table 2. Comparison of core material relative costs and their characteristics and benefits.

Core Material Family	***Relative Core Material Cost***	***Characteristics and Benefits***
Balsa Wood (closed end grain)	Low	Good shear strength, high fatigue endurance, easily bonded, easily finished, good temperature range, but absorbs moisture, potential for fungus
Polyurethane Foam (PUR)	Low	Good solvent resistance, good temperature capability, moderately fire resistant, wide density range of products
Polystyrene Foam (PS)	Low	Lowest temperature capability, lowest cost material, moderate mechanical properties, fairly fragile material
Polyvinylchloride Foam (PVC)	Low	High strength, high stiffness, easily bonded , good impact resistance, only moderate temperature capability
Polymethacrylimide Foam (PMI)	High	High dimensional stability at temperature, excellent mechanical properties, solvent resistance, low thermal conductivity, high strength and stiffness
Polyetherimide Foam (PEI)	High	Low moisture absorption, high thermal stability, high strength, good fire resistance, good dielectric properties
Styrene-acrylonitrile Copolymer Foam (SAN)	Moderate	No outgassing, high stiffness, high impact and fatigue strength, no environmental problems with resin or recycling
Epoxy Foam	Moderate	High strength and stiffness, compatible with numerous laminate systems, excellent high temperature properties, moderate fire resistance
Phenolic Foam	Moderate	Excellent fires/smoke/toxicity properties, somewhat brittle, good high temperature properties, very good insulator
Carbon/Graphite Foams	High	Excellent high temperature properties (best), high stiffness mechanical properties, high cost main deterrent, used as tooling materials as well as structures

3. *Fundamentals of Composites Manufacturing: Materials, Methods and Applications, Second Edition*, A.B. Strong, SME/Society of Manufacturing Engineers, 2008, ISBN 978-0872638-54-9.
4. *Honeycomb Technology: Materials, Design, Manufacturing, Applications and Testing*, T. Bitzer, Chapman & Hall, 1997, ISBN 0-412-54050-9.
5. *Resin Transfer Moulding for Aerospace Structures*, Edited by T.M. Kruckenberg and R. Paton, Kluwer Academic Publishers, 1998, ISBN 0-412-73150-9.