GFRP, epoxy matrix (isotropic)

Description

Image

Caption

1. Close-up of the back of the material. © Salawraspoo at en.wikipedia - (CC BY-SA 3.0) 2. Equipment operator demonstrates fiber glass repair techniques, repairing damage on a small boat. © U.S. Navy - Public domain

The material

Composites are one of the great material developments of the 20th century. Those with the highest stiffness and strength are made of continuous fibers (glass, carbon or Kevlar, an aramid) embedded in a thermosetting resin (polyester or epoxy). The fibers carry the mechanical loads, while the matrix material transmits loads to the fibers and provides ductility and toughness as well as protecting the fibers from damage caused by handling or the environment. It is the matrix material that limits the service temperature and processing conditions. Polyester-glass composites (GFRPs) are the cheapest and by far the most widely used. A recent innovation is the use of thermoplastics at the matrix material, either in the form of a co-weave of cheap polypropylene and glass fibers that is thermoformed, melting the PP, or as expensive high-temperature thermoplastic resins such as PEEK that allow composites with higher temperature and impact resistance. High performance GFRP uses continuous fibers. Those with chopped glass fibers are cheaper and are used in far larger quantities. GFRP products range from tiny electronic circuit boards to large boat hulls, body and interior panels of cars, household appliances, furniture and fittings.

Composition (summary)

Epoxy + continuous E-glass fiber reinforcement (0, +-45, 90), quasi-isotropic layup.

General properties

Density	109	-	123	lb/ft^3
Price	* 11	-	15.6	USD/lb
Date first used	1935			

Mechanical properties

Young's modulus	* 2.18	-	4.06	10^6 psi
Shear modulus	* 0.87	-	1.6	10^6 psi
Bulk modulus	2.61	-	2.9	10^6 psi
Poisson's ratio	* 0.314	-	0.315	
Yield strength (elastic limit)	* 16	-	27.8	ksi
Tensile strength	* 20	-	35	ksi
Compressive strength	* 20	-	30	ksi
Elongation	* 0.85	-	0.95	% strain
Hardness - Vickers	* 10.8	-	21.5	HV
Fatigue strength at 10^7 cycles	* 7.98	-	13.9	ksi
Fracture toughness	* 6.37	-	20.9	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 0.0028	-	0.005	

Thermal properties

Glass temperature	296	-	386	°F
Maximum service temperature	* 284	-	428	°F
Minimum service temperature	* -190	-	-99.7	°F
Thermal conductor or insulator?	Poor insulator			
Thermal conductivity	* 0.231	-	0.318	BTU.ft/h.ft^2.F
Specific heat capacity	* 0.239	-	0.287	BTU/lb.°F
Thermal expansion coefficient	* 4.8	-	18.3	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	* 2.4e21	-	1.91e22	µohm.cm
Dielectric constant (relative permittivity)	* 4.86	-	5.17	
Dissipation factor (dielectric loss tangent)	0.004	-	0.009	
Dielectric strength (dielectric breakdown)	* 300	-	500	V/mil

Optical properties

Transparency	Translucent

Processability

Moldability	4	-	5
Machinability	2	-	3

Eco properties

Embodied energy, primary production	* 1.63e4	-	1.84e4	kcal/lb
CO2 footprint, primary production	* 9.5	-	10.5	lb/lb
Recycle	✗			

Supporting information

Design guidelines

Polymer composites can be formed by closed or open mold methods. All the closed mold methods produce fiber orientation parallel to the mold surfaces (for extrusion, it is parallel to the inside surface of the orifice die). Of the open mold methods, all allow multidirectional fiber orientation parallel to the mold or mandrel, except pultrusion, where the fibers are oriented parallel to the laminate surface and the mold plates, and calendaring, where they are parallel to the sheet surface. Lay up methods allow complete control of fiber orientation; they are used for large one-off products that do not require a high fiber-resin ratio. Lamination and calendaring form sheets, pultrusion is used to make continuous shapes of constant cross section and filament winding produces large hollow items such as tubes, drums or other containers. Joints in long-fiber composite materials are sources of weakness because the fibers do not bridge the joint. Two or more laminates are usually joined using adhesives and, to ensure adequate bonding, an overlap length of 25mm for single- and double- lap joints or 40-50mm for strap, step and scarf joints is necessary. Holes in laminates dramatically reduce the failure strength making joining with fasteners difficult. Composite manufacture is labor intensive. It is difficult to predict the final strength and failure mode because defects are easy to create and hard to detect or repair.

Technical notes

The properties of long fiber composites are strongly influenced by the choice of fiber and matrix and the way in which these are combined: fiber-resin ratio, fiber length, fiber orientation, laminate thickness and the presence of fiber/resin coupling agents to improve bonding. Glass offers high strength at low cost; carbon has very high strength, stiffness and low density; Kevlar has high strength and low density, is flame retardant and transparent to radio waves (unlike carbon). Polyesters are the most widely used matrices as they offer reasonable properties at relatively low cost. The superior properties of epoxies and the temperature performance of polyimides can justify their use in certain applications, but they are expensive. The strength of a composite is increased by raising the fiber-resin ratio, and orienting the fibers parallel to the loading direction. The longer the fibers, the more efficient is the reinforcement at carrying the applied loads, but shorter fibers are easier to process and hence cheaper. Increased laminate thickness leads to reduced composite strength and modulus as there is an increased likelihood of entrapped voids. Coupling agents generally increase tensile strength. Environmental conditions affect the performance of composites: fatigue loading, moisture and heat all reduce allowable strength.

Typical uses

Sports equipment such as skis, racquets, skate boards and golf club shafts, ship and boat hulls; body shells; automobile components; cladding and fittings in construction; chemical plant.

Tradenames

Cycom, Fiberdux, Scotchply

Links

Reference

ProcessUniverse

Producers