Description

Image

Caption

1. Thermosetting polyester used as the matrix of fiber-reinforced boat parts. 2. Thermosetting polyester used as the matrix of fiber-reinforced car parts.

The material

Polyesters can be a thermosets, a thermoplastics or elastomers. The unsaturated polyester resins are thermosets. Most polyester thermosets are used in glass fiber/polyester composites. They are less stiff and strong than epoxies, but they are considerably cheaper.

Compositional summary

(OOC-C6H4-COO-C6H10)n

General properties

Density		1.04e3	-	1.4e3	kg/m^3
Price	*	4.06	-	4.17	USD/kg
Date first used		1942			

Mechanical properties

Young's modulus		2.07	-	4.41	GPa
Shear modulus	*	0.744	-	1.59	GPa
Bulk modulus		4.5	-	4.7	GPa
Poisson's ratio		0.381	-	0.403	
Yield strength (elastic limit)	*	33	-	40	MPa
Tensile strength		41.4	-	89.6	MPa
Compressive strength	*	36.3	-	44	MPa
Elongation		2	-	2.6	% strain
Hardness - Vickers		9.9	-	21.5	HV
Fatigue strength at 10^7 cycles	*	16.6	-	35.8	MPa
Fracture toughness	*	1.09	-	1.69	MPa.m^0.5

Mechanical loss coefficient (tan delta)	* 0.00907	-	0.0193	

Thermal properties

Glass temperature	147	-	207	°C
Maximum service temperature	130	-	150	°C
Minimum service temperature	* -123	-	-73.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	* 0.287	-	0.299	W/m.°C
Specific heat capacity	* 1.51e3	-	1.57e3	J/kg.°C
Thermal expansion coefficient	99	-	180	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e18	-	3e19	µohm.cm
Dielectric constant (relative permittivity)	2.8	-	3.3	
Dissipation factor (dielectric loss tangent)	* 0.001	-	0.03	
Dielectric strength (dielectric breakdown)	15	-	19.7	1000000 V/m

Optical properties

Transparency	Transparent		
Refractive index	1.54	-	1.57

Processability

Castability	3	-	4
Moldability	3	-	4
Machinability	3	-	4
Weldability	1		

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Limited use
Soils, alkaline (clay)	Unacceptable
Wine	Acceptable

Durability: acids

Acetic acid (10%)	Limited use
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	

	Unacceptable
Nitric acid (10%)	Excellent
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

Sodium hydroxide (10%)	Unacceptable
Sodium hydroxide (60%)	Unacceptable

Durability: fuels, oils and solvents

Amyl acetate	Limited use
Benzene	Unacceptable
Carbon tetrachloride	Excellent
Chloroform	Unacceptable
Crude oil	Excellent
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Excellent
Toluene	Limited use
Turpentine	Excellent
Vegetable oils (general)	Acceptable
White spirit	Limited use

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Limited use
Acetone	Limited use
Ethyl alcohol (ethanol)	Limited use
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Limited use

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable

Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Highly flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Geo-economic data for principal component

Annual world production, principal component		4e7	-	4.05e7	tonne/yr
Reserves, principal component	*	1e9	-	1.01e9	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	67.7	-	74.9	MJ/kg
CO2 footprint, primary production	*	2.83	-	3.12	kg/kg
Water usage	*	190	-	210	l/kg
Eco-indicator 99		437			millipoints/kg

Material processing: energy

Polymer molding energy	*	25.3	-	27.9	MJ/kg
Coarse machining energy (per unit wt removed)	*	1.82	-	2.01	MJ/kg
Fine machining energy (per unit wt removed)	*	13.9	-	15.3	MJ/kg
Grinding energy (per unit wt removed)	*	27.3	-	30.2	MJ/kg

Material processing: CO2 footprint

Polymer molding CO2	*	2.02	-	2.23	kg/kg
Coarse machining CO2 (per unit wt removed)	*	0.136	-	0.15	kg/kg
Fine machining CO2 (per unit wt removed)	*	1.04	-	1.15	kg/kg
Grinding CO2 (per unit wt removed)	*	2.05	-	2.26	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✘			
Recycle fraction in current supply	0.1			%
Downcycle	✔			
Combust for energy recovery	✔			
Heat of combustion (net)	* 28	-	29.4	MJ/kg
Combustion CO2	* 2.49	-	2.62	kg/kg
Landfill	✔			
Biodegrade	✘			
Toxicity rating	Non-toxic			
A renewable resource?	✘			

Environmental notes

Thermosetting polyesters cannot be recycled.

Supporting information

Design guidelines

Thermosetting polyesters are the cheapest resins for making glass or carbon fiber composites, but they have lower strength than epoxies. They can be formulated to cure at or above room temperature. Modifications can improve the chemical resistance, UV resistance and heat resistance without too much change in the ease of processing. Polyester elastomers have relatively high moduli and are stronger than polyurethanes. They have good melt flow properties, low shrinkage, good resistance to oils and fuels. Polyester can be made conductive by adding 30% carbon fiber. As a tape, Mylar is used for magnetic sound recording. Unfilled polyester thermosetting resins are normally used as surface coatings but they tend to be brittle. of Thermosetting polyester has a corroding influence on copper

Technical notes

Polyesters are made by a condensation reaction of an alcohol like ethyl alcohol (the one in beer) and an organic acid like acetic acid (the one in vinegar). The two react, releasing water, and forming an ester.

Typical uses

Laminated structures; Surface gel coatings; Liquid castings; Furniture products; Bowling balls; Simulated marble; Sewer pipe gaskets; Pistol grips; Television tube implosion barriers; Boats; Truck cabs; Concrete forms; Lamp housings; Skylights; Fishing rods.

Tradenames

Celanex, Eastar, Hytrel, Plenco, Rynite, Synolite, Valox, Vybrex

Links

Reference

ProcessUniverse

Producers