Flexible Polymer Foam (LD)

Description

Image

Caption

Polyurethane foam used for

The material

Polymer foams are made by the controlled expansion and solidification of a liquid or melt through a blowing agent; physical, chemical or mechanical blowing agents are possible. The resulting cellular material has a lower density, stiffness and strength than the parent material, by an amount that depends on its relative density - the volume-fraction of solid in the foam. Flexible foams can be soft and compliant, the material of cushions, mattresses, and padded clothing. Most are made from polyurethane, although latex (natural rubber) and most other elastomers can be foamed.

Composition (summary)

Hydrocarbon

General properties

Density		2.37	-	4.37	lb/ft^3
Price	*	1.18	-	1.31	USD/lb
Date first used		1947			

Mechanical properties

Young's modulus		1.45e-4	-	4.35e-4	10^6 psi
Shear modulus		5.8e-5	-	2.9e-4	10^6 psi
Bulk modulus		1.45e-4	-	4.35e-4	10^6 psi
Poisson's ratio		0.23	-	0.33	
Yield strength (elastic limit)		0.0029	-	0.0435	ksi
Tensile strength		0.0348	-	0.341	ksi
Compressive strength		0.0029	-	0.0435	ksi
Elongation		10	-	175	% strain
Hardness - Vickers		0.002	-	0.03	HV
Fatigue strength at 10^7 cycles	*	0.029	-	0.29	ksi

Fracture toughness	* 0.0137	-	0.0455	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 0.1	-	0.5	

Thermal properties

Melting point	233	-	350	°F
Glass temperature	-172	-	8.33	°F
Maximum service temperature	181	-	233	°F
Minimum service temperature	-99.7	-	-9.67	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.0231	-	0.0341	BTU.ft/h.ft^2.F
Specific heat capacity	0.418	-	0.54	BTU/lb.°F
Thermal expansion coefficient	63.9	-	122	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e20	-	1e23	µohm.cm
Dielectric constant (relative permittivity)	1.15	-	1.2	
Dissipation factor (dielectric loss tangent)	5e-4	-	0.003	
Dielectric strength (dielectric breakdown)	102	-	178	V/mil

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Processability

Castability	3	-	5
Moldability	1	-	4
Machinability	3	-	4
Weldability	1		

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Acceptable
Acetic acid (glacial)	Limited use

Citric acid (10%)	Acceptable
Hydrochloric acid (10%)	Limited use
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Limited use
Nitric acid (10%)	Limited use
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Unacceptable
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Acceptable
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Limited use
Sodium hydroxide (60%)	Limited use

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

Chlorine gas (dry)	Unacceptable
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable
Sulfur dioxide (gas)	Limited use

Durability: built environments

Industrial atmosphere	Acceptable
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Poor

Durability: flammability

Flammability	Highly flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Acceptable
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

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	1.12e4	-	1.24e4	kcal/lb
CO2 footprint, primary production	*	4.28	-	4.73	lb/lb
Water usage	*	25.9	-	28.6	gal(US)/lb
Eco-indicator 95		480			millipoints/kg
Eco-indicator 99		386			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	584	-	644	kcal/lb
Polymer molding energy	*	1.48e3	-	1.64e3	kcal/lb
Coarse machining energy (per unit wt removed)	*	52	-	57.4	kcal/lb
Fine machining energy (per unit wt removed)	*	56.6	-	62.5	kcal/lb
Grinding energy (per unit wt removed)	*	61.8	-	68.1	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	*	0.431	-	0.476	lb/lb
Polymer molding CO2	*	1.09	-	1.21	lb/lb
Coarse machining CO2 (per unit wt removed)	*	0.036	-	0.0398	lb/lb
Fine machining CO2 (per unit wt removed)	*	0.0392	-	0.0433	lb/lb
Grinding CO2 (per unit wt removed)					

	*	0.0427	-	0.0472	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle		✗			
Embodied energy, recycling	*	5.1e3	-	5.63e3	kcal/lb
CO2 footprint, recycling	*	3.7	-	4.09	lb/lb
Recycle fraction in current supply		8.02	-	8.86	%
Downcycle		✓			
Combust for energy recovery		✓			
Heat of combustion (net)	*	4.76e3	-	5e3	kcal/lb
Combustion CO2	*	3.06	-	3.22	lb/lb
Landfill		✓			
Biodegrade		✗			
Toxicity rating		Non-toxic			
A renewable resource?		✗			

Environmental notes

Foaming of insulation with CFCs has a damaging effect on the ozone layer - it is now abandoned. Monomers and foaming agents pose hazards; good practice overcomes these. For cushioning, the requirements are comfort and long life; polyurethane foams have been commonly used, but concerns about flammability and durability limit their use in furniture.

Supporting information

Design guidelines

Flexible foams have characteristics that suit them for cushioning and packaging of delicate objects. They are shaped by injecting or pouring a mix of polymer, catalyst and foaming agent into a mold where the agent evolves gas, expanding the foam. Expanding in a cold mold gives a solid surface skin. Closed cell foams float in water; open cell foams absorb liquids and act as sponges.

Technical notes

The properties of foams depend, most directly, on the material of which they are made and on the relative density (the fraction of the foam that is solid). Most commercial foams have a relative density between 1% and 30%. To a lesser extent, the properties depend on the size and the shape of the cells. Low density, closed cell, foams have exceptional low thermal conductivity. Skinned rigid foams have good bending stiffness and strength of low

Typical uses

Packaging, buoyancy, cushioning, sleeping mats, soft furnishings, artificial skin, sponges, carriers for inks and

Links

Reference

ProcessUniverse

Producers