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.

Compositional summary

Hydrocarbon

General properties

Density	38	-	70	kg/m^3
Price	* 2.61	-	2.88	USD/kg
Date first used	1947			

Mechanical properties

Young's modulus	0.001	-	0.003	GPa
Shear modulus	4e-4	-	0.002	GPa
Bulk modulus	0.001	-	0.003	GPa
Poisson's ratio	0.23	-	0.33	
Yield strength (elastic limit)	0.02	-	0.3	MPa
Tensile strength	0.24	-	2.35	MPa
Compressive strength	0.02	-	0.3	MPa
Elongation	10	-	175	% strain
Hardness - Vickers	0.002	-	0.03	HV
Fatigue strength at 10^7 cycles	* 0.2	-	2	MPa

Fracture toughness	* 0.015	-	0.05	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.1	-	0.5	

Thermal properties

Melting point	112	-	177	°C
Glass temperature	-113	-	-13.2	°C
Maximum service temperature	82.9	-	112	°C
Minimum service temperature	-73.2	-	-23.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.04	-	0.059	W/m.°C
Specific heat capacity	1.75e3	-	2.26e3	J/kg.°C
Thermal expansion coefficient	115	-	220	µstrain/°C

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)	4	-	7	1000000 V/m

Optical properties

Transparency	Opaque

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	*	103	-	114	MJ/kg
CO2 footprint, primary production	*	4.28	-	4.73	kg/kg
Water usage	*	216	-	239	l/kg
Eco-indicator 95		480			millipoints/kg
Eco-indicator 99		386			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	5.39	-	5.94	MJ/kg
Polymer molding energy	*	13.7	-	15.1	MJ/kg
Coarse machining energy (per unit wt removed)	*	0.48	-	0.53	MJ/kg
Fine machining energy (per unit wt removed)	*	0.522	-	0.577	MJ/kg
Grinding energy (per unit wt removed)	*	0.57	-	0.629	MJ/kg

Material processing: CO2 footprint

Polymer extrusion CO2	*	0.431	-	0.476	kg/kg
Polymer molding CO2	*	1.09	-	1.21	kg/kg
Coarse machining CO2 (per unit wt removed)	*	0.036	-	0.0398	kg/kg
Fine machining CO2 (per unit wt removed)	*	0.0392	-	0.0433	kg/kg
Grinding CO2 (per unit wt removed)	*	0.0427	-	0.0472	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✖			
Embodied energy, recycling	* 47.1	-	52	MJ/kg
CO2 footprint, recycling	* 3.7	-	4.09	kg/kg
Recycle fraction in current supply	8.02	-	8.86	%
Downcycle	✔			
Combust for energy recovery	✔			
Heat of combustion (net)	* 44	-	46.2	MJ/kg
Combustion CO2	* 3.06	-	3.22	kg/kg
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 weight

Typical uses

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

Links

Reference

ProcessUniverse

Producers