Polyurethane

Description

Image

Caption

1. Close-up of the material's surface. © Chris Lefteri 2. Bike seats with polyurethane cores. © Chris

The material

Think of polyurethanes and you think of the soft, the stretchy, materials and fabrics (Lycra or Spandex). Like PVC, polyurethanes have thermoplastic, elastomeric and thermosetting grades. They are easily foamed; some 40% of all PU is made into foam by mixing it with a blowing agent. The foams can be open- or closed-cell, microcellular or filter grades. They are the strongest of elastomers.

Compositional summary

(CO-NH-R-NH-CO-O-R-O)n

General properties

Density		1.02e3	-	1.25e3	kg/m^3
Price	*	5	-	6	USD/kg
Date first used		1941			

Mechanical properties

Young's modulus		0.002	-	0.03	GPa
Shear modulus		7e-4	-	0.008	GPa
Bulk modulus		1.5	-	1.6	GPa
Poisson's ratio		0.49	-	0.498	
Yield strength (elastic limit)		25	-	51	MPa
Tensile strength		25	-	51	MPa
Compressive strength		50	-	100	MPa
Elongation		380	-	720	% strain
Fatigue strength at 10^7 cycles	*	18.8	-	38.3	MPa
Fracture toughness		0.2	-	0.4	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	0.51	-	1.2	

Thermal properties

Glass temperature	-73.2	-	-23.2	°C
Maximum service temperature	66.9	-	86.9	°C
Minimum service temperature	* -73.2	-	-23.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.28	-	0.3	W/m.°C
Specific heat capacity	1.65e3	-	1.7e3	J/kg.°C
Thermal expansion coefficient	150	-	165	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e18	-	1e22	µohm.cm
Dielectric constant (relative permittivity)	5	-	9	
Dissipation factor (dielectric loss tangent)	0.003	-	0.009	
Dielectric strength (dielectric breakdown)	16	-	22	1000000 V/m

Optical properties

Transparency	Translucent

Processability

Castability	4	-	5
Moldability	4	-	5
Machinability	2	-	3
Weldability	1		

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Unacceptable
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Limited use
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Limited use
Nitric acid (70%)	Unacceptable

Phosphoric acid (10%)	Limited use
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Limited use
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

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

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	Excellent
Toluene	Limited use
Turpentine	Unacceptable
Vegetable oils (general)	Excellent
White spirit	Unacceptable

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

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

Durability: built environments

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

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	*	82.7	-	91.5	MJ/kg
CO2 footprint, primary production	*	3.52	-	3.89	kg/kg
Water usage	*	93.5	-	103	l/kg
Eco-indicator 99		386			millipoints/kg

Material processing: energy

Polymer molding energy	*	22	-	24.2	MJ/kg
Coarse machining energy (per unit wt removed)	*	1.1	-	1.22	MJ/kg
Fine machining energy (per unit wt removed)	*	6.76	-	7.47	MJ/kg
Grinding energy (per unit wt removed)	*	13	-	14.4	MJ/kg

Material processing: CO2 footprint

Polymer molding CO2	*	1.76	-	1.94	kg/kg
Coarse machining CO2 (per unit wt removed)	*	0.0827	-	0.0914	kg/kg
Fine machining CO2 (per unit wt removed)	*	0.507	-	0.56	kg/kg
Grinding CO2 (per unit wt removed)	*	0.978	-	1.08	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle		✘			
Recycle fraction in current supply		0.5	-	1	%
Downcycle		✔			
Combust for energy recovery		✔			
Heat of combustion (net)	*	21.8	-	22.9	MJ/kg
Combustion CO2	*	2	-	2.1	kg/kg
Landfill					

	✔
Biodegrade	✖
Toxicity rating	Non-toxic
A renewable resource?	✖

Environmental notes

Polyurethane elastomers are thermosets, and thus cannot be recycled. Their disposal creates an environmental problem.

Supporting information

Design guidelines

Urethanes have exceptional strength (up to 48 MPa) and abrasion resistance, low compression set and good fuel resistance. They have useful properties from -55 C to 90 C

Technical notes

Urethane elastomers (elPU) are co-polymers of diisocyanate and polyester.

Typical uses

Cushioning; packaging; shoe soles; tires; fuel hoses; gears; bearings; car bumpers; adhesives;

Links

Reference

ProcessUniverse

Producers