Polyurethane (tpPUR)

Description

Image

Caption

1. PUR wheels revolutionized skate board and roller skate technology. © Thinkstock 2. Close-up of the material on the wheels of roller blades. © Thinkstock

The material

Think of polyurethanes and you think of soft, stretchy materials and fabrics (Lycra or Spandex), but they can also be leathery or rigid. 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. PU is a versatile material.

General properties

Density		1.12e3	-	1.24e3	kg/m^3
Price	*	4.16	-	4.54	USD/kg
Date first used		1941			

Mechanical properties

Young's modulus		1.31	-	2.07	GPa
Shear modulus	*	0.465	-	0.735	GPa
Bulk modulus		2.9	-	3.1	GPa
Poisson's ratio	*	0.4	-	0.416	
Yield strength (elastic limit)	*	40	-	53.8	MPa
Tensile strength		31	-	62	MPa
Compressive strength	*	44	-	59.2	MPa
Elongation		60	-	550	% strain
Hardness - Vickers		16.1	-	22.7	HV
Fatigue strength at 10^7 cycles	*	16	-	20	MPa
Fracture toughness	*	1.84	-	4.97	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	0.0193	-	0.0305	

Thermal properties

Melting point	74.8	-	137	°C
Glass temperature	* 60	-	90	°C
Maximum service temperature	* 64.9	-	80	°C
Minimum service temperature	* -123	-	-73.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	* 0.235	-	0.244	W/m.°C
Specific heat capacity	* 1.55e3	-	1.62e3	J/kg.°C
Thermal expansion coefficient	90	-	144	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e18	-	3e19	µohm.cm
Dielectric constant (relative permittivity)	* 6.6	-	7.12	
Dissipation factor (dielectric loss tangent)	* 0.06	-	0.08	
Dielectric strength (dielectric breakdown)	15.1	-	16.4	1000000 V/m

Optical properties

Transparency	Transparent		
Refractive index	1.5	-	1.6

Processability

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

Durability: water and aqueous solutions

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

Durability: acids

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

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

Durability: alkalis

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

Durability: fuels, oils and solvents

Amyl acetate	Unacceptable
Benzene	Unacceptable
Carbon tetrachloride	Unacceptable
Chloroform	Unacceptable
Crude oil	Unacceptable
Diesel oil	Limited use
Lubricating oil	Limited use
Paraffin oil (kerosene)	Acceptable
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)	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 extrusion energy	* 5.79	-	6.4	MJ/kg
Polymer molding energy	* 17.9	-	19.8	MJ/kg
Coarse machining energy (per unit wt removed)	* 1.09	-	1.21	MJ/kg
Fine machining energy (per unit wt removed)	* 6.66	-	7.36	MJ/kg
Grinding energy (per unit wt removed)	* 12.8	-	14.2	MJ/kg

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.435	-	0.48	kg/kg
Polymer molding CO2	* 1.34	-	1.48	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.082	-	0.0906	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.499	-	0.552	kg/kg
Grinding CO2 (per unit wt removed)	* 0.963	-	1.06	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 36.3	-	40.1	MJ/kg
CO2 footprint, recycling	* 2.85	-	3.15	kg/kg

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

PU is synthesizes from diisocyanate and a polyester or polyether. The diisocyanate is toxic, requiring precautions during production. PU itself is inert and non-toxic. The flammability of PU foam, and the use of CFC's as blowing agents in the foaming process were, at one time, a cause for concern. New flame retardants now mean that PU foams meet current fire safety standards, and CFC's have been replaced by CO2 and HFC's which do not have a damaging effect on the ozone layer. Thermoplastic PUs can be recycled (thermosetting PUs cannot), and when all useful life is over, incinerated to recover heat. Legislation for return of packaging and disposal problems may disadvantage PU.

Recycle mark

Supporting information

Design guidelines

PU foams are cheap, easy to shape, and have good structural performance and resistance to hydrocarbons. Most foamable PUs are thermosets, so they are shaped by casting rather than heat-molding, giving a high surface finish and the potential for intricate shapes. In solid form PUs can be produced as sheet or bulk shapes - as a thermoplastic or an elastomer. For load-bearing applications as power-transmission belts and conveyer belts tpPUs are reinforced with nylon or aramid fibers, giving flexibility with high strength. tpPUs can have a wide range of hardness, softening point and water absorption. They are processed in the same way as nylon, but are considerably more expensive. tpPU fibers are hard, wiry and have a low softening point compared to nylon, but they have been used as bristles on brushes; elPU fibers are much more common - they are used in clothing and flexible products under the trade-name of Spandex or Lycra. elPU foams are used for mattresses, seating of furniture and packaging; more rigid foams appear as crash protection in cars, and, in low-density form (95% gas) as insulation in refrigerators and freezers. These flexible resins are good in laminate systems where damping is required. elPU is amorphous, tpPU is crystalline; elPU is commonly cast or drawn, tpPU is commonly injection molded or extruded. PU foam is usually processed by reaction injection molding: the resin and hardener are mixed and injected into a mold where they react and set. PU can be bonded with polyurethane, nitrile, neoprene, epoxies and cyan-acrylates adhesives. It has good resistance to hydrocarbons, degrades in many solvents and is slow burning in fire.

Technical notes

Almost all polyurethanes are co-polymers of linked polyester, alcohols and isocyanate groups. Depending on the mix, polyurethanes can be soft and elastic (Lycra, Spandex) or near-rigid (track-shoe soles, floor tiles), making PU one of the most versatile of polymers.

Typical uses

Cushioning and seating, packaging, running shoe soles, tires, wheels, fuel hoses, gears, bearings, wheels, car bumpers, adhesives, fabric-coatings for inflatables, transmission belts, diaphragms, coatings that are resistant to dry-cleaning, furniture, thermal insulation in refrigerators and freezers.

Tradenames

Tecoflex, Tecothane, Desmopan, Texin

Links

Reference

ProcessUniverse

Producers