Polyvinylchloride (tpPVC)

Description

Image

Caption

These boat fenders illustrate that PVC is tough, weather resistant and easy to form and color.

The material

PVC - Vinyl - is one of the cheapest, most versatile and - with polyethylene - the most widely used of polymers and epitomizes their multi-facetted character. In its pure form - as a thermoplastic, tpPVC - it is rigid, and not very tough; its low price makes it a cost-effective engineering plastic where extremes of service are not encountered. Incorporating plasticizers creates flexible PVC, elPVC, a material with leather-like or rubber-like properties, and used a substitute for both. By contrast, reinforcement with glass fibers gives a material that is sufficiently stiff, strong and tough to be used for roofs, flooring and building panels. Both rigid and flexible PVC can be foamed to give lightweight structural panels, and upholstery for cars and domestic use. Blending with other polymers extends the range of properties further: vinyl gramophone records were made of a vinyl chloride/acetate co-polymer; blow molded bottles and film are a vinyl chloride/acrylic copolymer.

Composition (summary)

(CH2CHCl)n

General properties

Density	81.2	-	98.6	lb/ft^3
Price	* 0.912	-	1.01	USD/lb
Date first used	1940			

Mechanical properties

Young's modulus	0.31	-	0.6	10^6 psi
Shear modulus	0.111	-	0.216	10^6 psi
Bulk modulus	0.682	-	0.711	10^6 psi
Poisson's ratio	0.383	-	0.407	
Yield strength (elastic limit)	5.13	-	7.56	ksi
Tensile strength	5.9	-	9.45	ksi
Compressive strength	6.16	-	13	ksi
Elongation	11.9	-	80	% strain
Hardness - Vickers	10.6	-	15.6	HV
Fatigue strength at 10^7 cycles	2.35	-	3.78	ksi
Fracture toughness	1.33	-	4.66	ksi.in^0.5
Mechanical loss coefficient (tan delta)	0.00966	-	0.0187	

Thermal properties

Glass temperature	167	-	221	°F
Maximum service temperature	140	-	158	°F

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Minimum service temperature	-190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.0849	-	0.169	BTU.ft/h.ft^2.F
Specific heat capacity	0.324	-	0.345	BTU/lb.°F
Thermal expansion coefficient	55.6	-	83.3	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e20	-	1e22	µohm.cm
Dielectric constant (relative permittivity)	3.1	-	4.4	
Dissipation factor (dielectric loss tangent)	0.03	-	0.1	
Dielectric strength (dielectric breakdown)	351	-	500	V/mil

Optical properties

Transparency	Translucent			
Refractive index	1.54	-	1.56	

Processability

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

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Acceptable
Nitric acid (10%)	Unacceptable
Nitric acid (70%)	Excellent
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Acceptable
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

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

Durability: fuels, oils and solvents

Amyl acetate	Unacceptable
Benzene	Limited use
Carbon tetrachloride	Excellent
Chloroform	Limited use
Crude oil	Acceptable
Diesel oil	Acceptable

Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Acceptable
Toluene	Unacceptable
Turpentine	Acceptable
Vegetable oils (general)	Acceptable
White spirit	Acceptable

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

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

Durability: built environments

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

Durability: flammability

Flammability	Self-extinguishing

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

Geo-economic data for principal component

Annual world production		4.82e7	- 5.02e7	ton/yr
Reserves	*	1.36e9	- 1.38e9	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	6e3	- 6.63e3	kcal/lb
CO2 footprint, primary production	*	2.37	- 2.62	lb/lb
Water usage	*	23.6	- 26.1	gal(US)/lb
Eco-indicator 95		270		millipoints/kg
Eco-indicator 99		170		millipoints/kg

Material processing: energy

Polymer extrusion energy	*	612	- 677	kcal/lb
Polymer molding energy	*	1.52e3	- 1.67e3	kcal/lb

Coarse machining energy (per unit wt removed)	* 81.4	-	89.9	kcal/lb
Fine machining energy (per unit wt removed)	* 351	-	388	kcal/lb
Grinding energy (per unit wt removed)	* 650	-	718	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.424	-	0.469	lb/lb
Polymer molding CO2	* 1.05	-	1.16	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0564	-	0.0623	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.243	-	0.268	lb/lb
Grinding CO2 (per unit wt removed)	* 0.45	-	0.498	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 3.71e3	-	4.1e3	kcal/lb
CO2 footprint, recycling	* 2.69	-	2.97	lb/lb
Recycle fraction in current supply	0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 1.9e3	-	1.99e3	kcal/lb
Combustion CO2	* 1.37	-	1.44	lb/lb
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

The vinyl chloride monomer is thoroughly nasty stuff, leading to pressure to discontinue production. But properly controlled, the processing is safe, and the polymer PVC has no known harmful effects. Disposal, however, can be a problem: thermal degradation releases chlorine, HCl and other toxic compounds, requiring special high-temperature incineration for safety.

Recycle mark

Supporting information

Design guidelines

In its pure form, PVC is heavy, stiff and brittle. Plasticizers can transform it from a rigid material to one that is almost as elastic and soft as rubber. Plasticized PVC is used as a cheap substitute for leather, which it can be made to resemble in color and texture. It is less transparent than PMMA or PC, but it also costs much less, so it is widely used for transparent, disposable containers. PVC is available as film, sheet or tube. It can be joined with polyester, epoxy or polyurethane adhesives. It has excellent resistance to acids and bases and good barrier properties to atmospheric gasses, but poor resistance to some solvents.

Technical notes

PVC can be a thermoplastic or a thermoset. There are many types of PVC: expanded rigid PVC, type I, type II, CPVC, acrylic/PVC blend, clear PVC.

Typical uses

tpPVC: pipes, fittings, profiles, road signs, cosmetic packaging, canoes, garden hoses, vinyl flooring, windows and cladding, vinyl records, dolls, medical tubes. elPVC: artificial leather, wire insulation, film, sheet, fabric, car upholstery.

Tradenames

Conoco, Dural, Ethyl, Flexalloy, Geon, Hy-vin, Keysor, Locovyl, Novatemp, Oxyclear, Polyvin, Satinflex, Sicron, Solvic, Solvin, Superkleen, Trosiplast, Unichem, Vestolit, Vinoflex, Vistel

Links

Reference

ProcessUniverse

Producers