Natural rubber (NR)

Description

Image

Caption

1. Rubber trees in Kerala, India © M.arunprasad at en.wikipedia - (CC BY-SA 3.0) 2. Rubber bands in different colors. © Bill Ebbesen at en.wikipedia - (CC BY-SA 3.0)

The material

Natural Rubber was known to the natives of Peru many centuries ago, and is now one of Malaysia's main exports. It made the fortune of Giles Macintosh who, in 1825, devised the rubber-coated waterproof coat the still bears his name. Latex, the sap of the rubber tree, is cross-linked (vulcanized) by heating with sulfur; the amount of the cross-linking determines the properties. It is the most widely used of all elastomers - more than 50% of all produced.

Compositional summary

(CH2-C(CH3)-CH-CH2)n

General properties

Density		57.4	-	58.1	lb/ft^3
Price	*	0.862	-	1.09	USD/lb
Date first used		1751			

Mechanical properties

Young's modulus		2.18e-4	-	3.63e-4	10^6 psi
Shear modulus		8.7e-5	-	1.16e-4	10^6 psi
Bulk modulus	*	0.203	-	0.218	10^6 psi
Poisson's ratio		0.499	-	0.5	
Yield strength (elastic limit)		2.9	-	4.35	ksi
Tensile strength		3.19	-	4.64	ksi
Compressive strength		3.19	-	4.79	ksi
Elongation		500	-	800	% strain
Fatigue strength at 10^7 cycles		0.609	-	0.653	ksi
Fracture toughness		0.137	-	0.228	ksi.in^0.5
Mechanical loss coefficient (tan delta)	*	0.8	-	1.9	

Thermal properties

Glass temperature	-109	-	-81.7	°F
Maximum service temperature	156	-	224	°F
Minimum service temperature	-69.1	-	-45.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.0578	-	0.0809	BTU.ft/h.ft^2.F
Specific heat capacity	0.43	-	0.597	BTU/lb.°F
Thermal expansion coefficient	83.3	-	250	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e15	-	1e16	µohm.cm
Dielectric constant (relative permittivity)	3	-	4.5	
Dissipation factor (dielectric loss tangent)	7e-4	-	0.003	
Dielectric strength (dielectric breakdown)	406	-	584	V/mil

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)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

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

Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

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

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Limited use
Acetone	Excellent
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)	Unacceptable
Sulfur dioxide (gas)	Unacceptable

Durability: built environments

Industrial atmosphere	Excellent			
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			

Geo-economic data for principal component

Annual world production, principal component	7.64e6	-	7.68e6	ton/yr

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 6.96e3	-	7.69e3	kcal/lb
CO2 footprint, primary production	* 1.97	-	2.18	lb/lb
Water usage	* 1.8e3	-	2.4e3	gal(US)/lb
Eco-indicator 95	360			millipoints/kg
Eco-indicator 99	23.7			millipoints/kg

Material processing: energy

Polymer molding energy	* 1.66e3	-	1.83e3	kcal/lb
Grinding energy (per unit wt removed)	* 683	-	754	kcal/lb

Material processing: CO2 footprint

Polymer molding CO2	* 1.23	-	1.35	lb/lb
Grinding CO2 (per unit wt removed)	* 0.472	-	0.522	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✗			
Recycle fraction in current supply	0.1			%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 4.6e3	-	4.84e3	kcal/lb
Combustion CO2	* 3.15	-	3.31	lb/lb

Landfill	✓
Biodegrade	✗
Toxicity rating	Non-toxic
A renewable resource?	✓

Environmental notes

Natural rubber is a biopolymer. Once vulcanized, natural rubbers are thermosets, and thus cannot be recycled. Their disposal creates an environmental problem.

Supporting information

Design guidelines

Natural rubber is an excellent, cheap, general-purpose elastomer with large stretch capacity and useful properties from -50 C to 115 C, but with poor oil, oxidation, ozone and UV resistance. It has low hysteresis - and is thus very bouncy.

Typical uses

Gloves, Car tires, seals, belts, anti-vibration mounts, electrical insulation, tubing, rubber lining pipes and

Links

Reference

ProcessUniverse

Producers