Polyamides (Nylons, PA)

Description

Image

Caption

1. Knot tied in a polyamide rope. © Brighterorange at en.wikipedia - (CC BY-SA 3.0) 2. Locking nut with polyamide insert to lock its screw in place. © Cav at en.wikipedia - Public domain 3. Students creating Nylon-6,6 in the laboratory at the University

The material

Back in 1945, the war in Europe just ended, the two most prized luxuries were cigarettes and nylons. Nylon (PA) can be drawn to fibers as fine as silk, and was widely used as a substitute for it. Today, newer fibers have eroded its dominance in garment design, but nylon-fiber ropes, and nylon as reinforcement for rubber (in car tires) and other polymers (PTFE, for roofs) remains important. It is used in product design for tough casings, frames and handles, and - reinforced with glass - as bearings gears and other load-bearing parts. There are many grades (Nylon 6, Nylon 66, Nylon 11….) each with slightly different properties.

Composition (summary)

(NH(CH2)5C0)n

General properties

Density	69.9	-	71.2	lb/ft^3
Price	* 1.85	-	2.04	USD/lb
Date first used	1938			

Mechanical properties

Young's modulus	0.38	-	0.464	10^6 psi
Shear modulus	* 0.141	-	0.172	10^6 psi
Bulk modulus	0.537	-	0.566	10^6 psi
Poisson's ratio	0.34	-	0.36	
Yield strength (elastic limit)	7.25	-	13.7	ksi
Tensile strength	13.1	-	23.9	ksi
Compressive strength	7.98	-	15.1	ksi
Elongation	30	-	100	% strain
Hardness - Vickers	25.8	-	28.4	HV
Fatigue strength at 10^7 cycles	* 5.22	-	9.57	ksi
Fracture toughness	* 2.02	-	5.11	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 0.0125	-	0.0153	

Thermal properties

Melting point	410	-	428	°F
Glass temperature	111	-	133	°F
Maximum service temperature	230	-	284	°F

Minimum service temperature	* -190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.135	-	0.146	BTU.ft/h.ft^2.F
Specific heat capacity	* 0.382	-	0.398	BTU/lb.°F
Thermal expansion coefficient	80	-	83	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	* 1.5e19	-	1.4e20	µohm.cm
Dielectric constant (relative permittivity)	3.7	-	3.9	
Dissipation factor (dielectric loss tangent)	0.014	-	0.03	
Dielectric strength (dielectric breakdown)	384	-	417	V/mil

Optical properties

Transparency	Translucent		
Refractive index	1.52	-	1.53

Processability

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

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Acceptable
Acetic acid (glacial)	Acceptable
Citric acid (10%)	Acceptable
Hydrochloric acid (10%)	Unacceptable
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%)	Unacceptable
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	Excellent
Carbon tetrachloride	Excellent
Chloroform	Acceptable
Crude oil	Acceptable
Diesel oil	Excellent

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

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Acceptable
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)	Excellent

Durability: built environments

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

Durability: flammability

Flammability	Slow-burning

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		3.64e6	-	3.69e6	ton/yr
Reserves	*	9.05e8	-	9.15e8	I. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	1.25e4	-	1.38e4	kcal/lb
CO2 footprint, primary production	*	7.58	-	8.38	lb/lb
Water usage	*	21.1	-	23.2	gal(US)/lb
Eco-indicator 95		630			millipoints/kg
Eco-indicator 99		495			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	638	-	706	kcal/lb
Polymer molding energy	*	2.24e3	-	2.48e3	kcal/lb

Coarse machining energy (per unit wt removed)	* 142	-	157	kcal/lb
Fine machining energy (per unit wt removed)	* 956	-	1.06e3	kcal/lb
Grinding energy (per unit wt removed)	* 1.86e3	-	2.06e3	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.442	-	0.489	lb/lb
Polymer molding CO2	* 1.55	-	1.72	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0982	-	0.109	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.662	-	0.731	lb/lb
Grinding CO2 (per unit wt removed)	* 1.29	-	1.42	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 4.37e3	-	4.82e3	kcal/lb
CO2 footprint, recycling	* 3.17	-	3.5	lb/lb
Recycle fraction in current supply	* 0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 3.26e3	-	3.42e3	kcal/lb
Combustion CO2	* 2.28	-	2.39	lb/lb
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

Nylons have no known toxic effects, although they are not entirely inert biologically. Nylons are oil-derivatives, but this will not disadvantage them in the near future. With refinements in polyolefin catalysis, nylons face stiff competition from less expensive polymers.

Recycle mark

Supporting information

Design guidelines

Nylons are tough, strong and have a low coefficient of friction, with useful properties over a wide range of temperature (-80 to +120 C). They are easy to injection mold, machine and finish, can be thermally or ultrasonically bonded, or joined with epoxy, phenol-formaldehyde or polyester adhesives. Certain grades of nylon can be electroplated allowing metallization, and most accept print well. A blend of PPO/Nylon is used in fenders, exterior body parts. Nylon fibers are strong, tough, elastic and glossy, easily spun into yarns or blended with other materials. Nylons absorb up to 4% water; to prevent dimensional changes, they must be conditioned before molding, allowing them to establishing equilibrium with normal atmospheric humidity. Nylons have poor resistance to strong acids, oxidizing agents and solvents, particularly in transparent grades.

Technical notes

The density, stiffness, strength, ductility and toughness of Nylons all lie near the average for unreinforced polymers. Their thermal conductivities and thermal expansion are a little lower than average. Reinforcement with mineral, glass powder or glass fiber increases the modulus, strength and density. Semi-crystalline nylon is distinguished by a numeric code for the material class indicating the number of carbon atoms between two nitrogen atoms in the molecular chain. The amorphous material is transparent; the semi-crystalline material is opal white.

Typical uses

Light duty gears, bushings, sprockets and bearings; electrical equipment housings, lenses, containers, tanks, tubing, furniture casters, plumbing connections, bicycle wheel covers, ketchup bottles, chairs, toothbrush bristles, handles, bearings, food packaging. Nylons are used as hot-melt adhesives for book bindings; as fibers - ropes, fishing line, carpeting, car upholstery and stockings; as aramid fibers - cables, ropes, protective clothing, air filtration bags and electrical insulation.

Tradenames

Adell, Akulon, Albis, Amilan, Ashlene, Capron, Celanese, Chemlon, Durethan, Gapex, Grilon, Grivory, Hylon, Kopa, Latamid, Lubrilon, Magnacomp, Maranyl, Minlon, NSC, Nivionplast, Novamid, Nydur, Nylamid, Nylene, Nypel, Orgamide, Radilon, Schulamid, Selar, Sniamid, Star-C, Star-L, Staramide, Texalon, Ultramid, Vestamid, Wellamid, Zytel

Links

Reference

ProcessUniverse

Producers