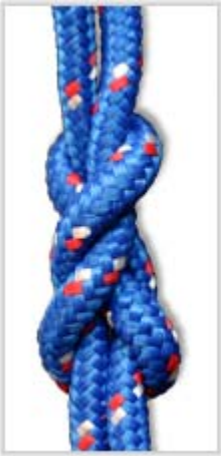
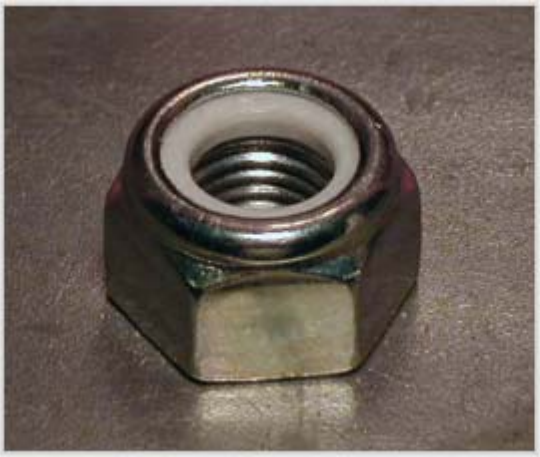
# Polyamides (Nylons, PA)

## 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.

### Compositional summary

(NH(CH2)5C0)n

## General properties

| | | | | | |
|---|---|---|---|---|---|
| Density | | 69.9 | - | 71.2 | lb/ft^3 |
| Price | * | 1.68 | - | 1.89 | 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, principal component | 3.64e6 | - | 3.69e6 | ton/yr |
| Reserves, principal component | * 9.05e8 | - | 9.15e8 | l. 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