PA (Polyamide/Nylon)

General information

Overview

A broad group of polymers characterised by "amide" chemistry, known for their strength, light-weight, and durability. They range from the classic Nylon 6/6 to glass-filled polythalamide (metal replacement) to Kevlar (bullet proof vests). Proteins (which include silk) are natural polyamides.

Strengths

Tough and strong. Low coefficient of friction. Good slip and wear properties. Resistant to many solvents, e.g. oils, fuels, ketones, and weak alkalis. Good fatigue resistance. Addition of glass fibers causes a useful improvement in stiffness, unlike POM. Some grades can have better low temperature toughness than POM or PBT. Can be sterilized with boiling water.

Limitations

All PA's absorb water and this can lead to dimensional instability and properties changing according to the relative humidity. Water absorption reduces tensile strength and modulus, though increases toughness and flexibility - property changes may be significant (50% or more) though vary widely according to temperature and the PA type. Not resistant to strong acids or alkalis. Natural colorants (e.g. tea, coffee, fruit juice) can stain PA. Unless flame-retarted with additives, most PA will continue to burn after the withdrawal of ignition source. Relatively high processing temperature with high volume contraction on solidification leads to voids in thick walled parts. Poor UV resistance leading to embrittlement and color change, in the absense of UV stabalizing additives.

Designation

Polyamide, PA, Nylon. Refer to the ISO 1864 standard for a detailed designation and specification system for polyamide.

Composition overview

Compositional summary

Polyamide are classified as either AB-type chemistry such as PA66, 46, or 6T (made from diamine and a dicarboxylic acid by condensation polymerization) and A type chemistry such as PA6 or PA12 (made from addition polymerisation of a lactam). Polyamide chemistry can, in general, be deduced from it code of the form PA<AB>, where A specifies a diamine (H2N-R-NH2) and B specifies a dicarboxylic acid (HO2C-R'-CO2H) or PA<A> where A specifies a lactam or amine-acid (H2N-R''-CO2H). So PA46 means a condensation polymer made from the 4-carbon diamine (R= -(CH2)4-) and a 6-carbon dicarboxylic acid (R'= -(CH2)4-), PA6 means an addition polymer of the 6-carbon lactam, caprolactam ((CH2)5-CONH), and PA6T means a polymer of a 6-carbon diamine (R=(CH2)6) and terephthalic acid (R'=C6H4). The CH2/CONH ratio is equal to the type number minus 1 for AB-polymers but equal to the average of the first number and the second number -2 in AA/BB-polymers, e.g. PA 610, the CH2/CONH ratio is 7 (the average of 6 and 8).

Material family	Plastic (thermoplastic, semi-crystalline)
Base material	PA6 (Polyamide/nylon 6)

Effect of composition

With increasing CH2/CONH ratio, the water absorption rate for PAs decreases. Higher numbered PAs have greater ratios, i.e. that for PA 12 is larger than that for PA 6. With increasing distance between the amide groups (higher CH2/CONH ratio) the density of intermolecular bonds decreases, leading to higher softness and lower melting temperature. High cooling rate produces lower crystallinity and corresponding high toughness. Slow cooling rate leads to high strength, high modulus of elasticity, high abrasion resistance, and low water absorption. Absorption of water increases toughness and abrasion resistance and decreases modulus of elasticity. Water absorption also causes an increase in volume. With increasing water content, electrical surface resistivity drops to such low values that electrostatic attraction does not need to be considered. Can be stabilized for long term use outdoors with addition of approx. 2% carbon black.

Processing properties

First commercial production	1938

Available forms

Specific casting grades available to avoid voiding. Also fire retardant and UV stabilized grades.

Forming

All standard processing methods for thermoplastics. Pre-drying of molding compounds required, semi-crystalline PAs have very low melt viscosities and so special grades are necessary for extrusion and blow-molding, very good for intricate injection moldings (low melt viscosities), rotational molding, and structural foam-molding possible.

Machining

All unfilled grades easy to machine

Joining

Can be bonded with adhesives based on cyanoacrylates or two-component EP resins. Bonding with cresols and resorcinol possible but not used due to environmental/health concerns. Suitable for all forms of welding (friction best, radio freq. difficult).

Surface treatment

Suitable for painting (though flexible grades less so), takes print well. Certain grades can be electroplated.

Geo-economic data for principal component

Annual world production	3.46e6	-	3.83e6	ton/yr

Notes

Other notes

The names "PA XY" and "PA X/Y" are often interchanged, e.g. in general, PA 66 is the same as PA 6/6, even though technically, PA 66 would be different (a PA containing sixty six carbon atoms in the basic unit, while 6/6 would be a PA with two basic units, each containing 6 carbon atoms). PA 6 and PA 66 have the same CH2/CONH ratio.