

Material Properties of Polyamide 6 (PA6) and Polyamide 66 (PA66)

July 9, 2026

Contents

Introduction	2
Chemical Structure	2
Thermal Properties	3
Mechanical Properties	4
Moisture Absorption Behavior	4
Processing Methods	5
Typical Applications	6

Introduction

Polyamides are a class of high-performance thermoplastics widely utilized in engineering applications due to their excellent balance of mechanical strength, thermal stability, chemical resistance, and processability. Among these, Polyamide 6 (PA6) and Polyamide 66 (PA66) stand out as two of the most commercially significant members, extensively employed across automotive, electrical, industrial machinery, and consumer goods sectors. Their ability to replace metals in structural components contributes significantly to lightweighting and cost reduction initiatives. This document provides a comprehensive technical overview of PA6 and PA66, focusing on their fundamental material properties—chemical structure, thermal behavior, mechanical performance, moisture absorption characteristics, processing methodologies, and typical applications. The information presented is intended for engineering and industrial use, offering a reliable reference for material selection and design.

Chemical Structure

The distinct properties of PA6 and PA66 originate from their unique molecular architectures, which are defined by their respective monomers and polymerization mechanisms. Polyamide 6 (PA6), also known as Nylon 6, is synthesized through the ring-opening polymerization of ϵ -caprolactam. This process yields a polymer chain with a repeating unit of $-\text{[NH}-(\text{CH}_2)_5\text{]-CO}-$, resulting in a single amide group per repeat segment. In contrast, Polyamide 66 (PA66), or Nylon 66, is produced via the condensation polymerization of hexamethylenediamine and adipic acid. This reaction forms a repeating unit of $-\text{[NH}-(\text{CH}_2)_4\text{]-NH-CO-(CH}_2)_4\text{-CO}-$, incorporating two amide groups per repeat unit. The higher density of polar amide ($-\text{CONH}-$) groups in PA66 facilitates a greater number of intermolecular hydrogen bonds compared to PA6. This enhanced hydrogen bonding network is a primary factor contributing to PA66's superior crystallinity, melting point, and overall thermal and mechanical performance. Both materials are semi-crystalline polymers, where the ordered

crystalline regions provide rigidity and heat resistance, while the amorphous domains impart toughness and impact resistance.

Thermal Properties

The thermal performance of PA6 and PA66 is a critical determinant of their suitability for various service environments, particularly those involving elevated temperatures. A key differentiating factor is the melting point (T_m). PA6 typically exhibits a T_m in the range of 210–225 °C, whereas PA66 demonstrates a significantly higher T_m , generally between 250–270 °C. This difference is directly attributable to the more regular chain structure and higher hydrogen bond density in PA66, which requires more energy to disrupt the crystalline lattice. The glass transition temperature (T_g), representing the onset of large-scale molecular motion in the amorphous phase, is approximately 45–70 °C for both materials under dry conditions. However, PA66 often shows a slightly higher effective T_g due to its stronger intermolecular forces.

Heat deflection temperature (HDT) is a crucial indicator of a material's load-bearing capability at elevated temperatures. For unreinforced grades, HDT values are relatively low; PA6 has an HDT of approximately 59–65 °C at 1.8 MPa, while PA66 is similar. The most significant enhancement comes from reinforcement, particularly with glass fibers. A 30% glass fiber (GF)-reinforced PA6 can achieve an HDT exceeding 210 °C at 1.8 MPa, whereas a similarly reinforced PA66 grade can reach 250 °C or higher. This substantial improvement allows both materials to be used in demanding under-the-hood automotive applications. The continuous use temperature for unfilled PA6 is generally around 110–130 °C, while PA66 can withstand continuous exposure up to approximately 150 °C. Thermal decomposition begins above 300 °C for PA6 and above 350 °C for PA66, highlighting PA66's superior thermal stability.

Mechanical Properties

The mechanical properties of PA6 and PA66 exhibit a characteristic trade-off between stiffness, strength, and toughness, further modulated by environmental conditioning and reinforcement. In the dry-as-molded state, unreinforced PA66 generally offers higher tensile strength (70–85 MPa) and modulus (approximately 2.5–3.0 GPa) compared to PA6 (tensile strength: 60–75 MPa, modulus: ~2.8 GPa), reflecting its greater inherent rigidity. Flexural strength follows a similar trend, with PA66 typically ranging from 100–120 MPa versus 80–100 MPa for PA6. While PA66 excels in stiffness and strength, PA6 often demonstrates superior ductility and impact resistance, especially after moisture conditioning. Unnotched impact strengths for PA6 can reach 80–100 kJ/m², while PA66 ranges from 90–120 kJ/m². Notched Izod/Charpy impact strength for dry PA6 is typically 4.2–4.4 kJ/m², whereas dry PA66 is lower, around 2.5 kJ/m², indicating higher notch sensitivity.

Reinforcement with glass fibers dramatically alters this profile. Adding 30% GF significantly increases tensile and flexural strength and modulus for both polymers, often doubling or tripling the values. For example, PA6-GF30 can achieve tensile strengths of 150–170 MPa and a modulus of 8–9 GPa. Similarly, PA66-GF30 grades can exceed 160 MPa in tensile strength with a modulus reaching 10–13 GPa. This reinforcement also elevates the HDT into the 200–250+ °C range. Hardness, measured on the Rockwell R scale, is typically in the range of R110–R120 for both unreinforced and reinforced grades. It is important to note that absorbed moisture acts as a plasticizer, reducing the stiffness and strength of both materials but simultaneously increasing their elongation at break and impact toughness.

Moisture Absorption Behavior

Moisture absorption is a defining characteristic of polyamides, profoundly influencing their dimensional stability and mechanical performance. The polar amide groups readily form hydrogen bonds with water molecules, leading to

significant hygroscopicity. Equilibrium moisture absorption at standard conditions of 23°C and 50% relative humidity (RH) is approximately 2.5–2.8% for PA6 and 2.5% for PA66. However, the saturation water uptake under immersion conditions reveals a stark difference: PA6 can absorb up to 7–9% water, while PA66 absorbs only 3–4%. This lower equilibrium and saturation moisture content in PA66 is attributed to its higher degree of crystallinity and denser hydrogen bonding network, which limits the penetration and retention of water molecules within the polymer matrix.

The consequences of moisture absorption are multifaceted. Dimensional changes occur as the material swells, with linear expansion coefficients being significantly higher in the transverse direction than in the flow direction, especially for unreinforced grades. Mechanically, absorbed water reduces the glass transition temperature, leading to a decrease in stiffness, tensile strength, and heat deflection temperature. Conversely, it enhances ductility and impact resistance, making conditioned parts less brittle. This necessitates careful consideration during product design, including the application of appropriate shrinkage allowances and the prediction of final part dimensions based on expected service conditions. To prevent defects such as splay, voids, and hydrolytic degradation during processing, both PA6 and PA66 must be thoroughly dried before molding. A target moisture content of $\leq 0.1\%$ is recommended, typically achieved by drying at 80–100 °C for 4–16 hours, depending on the initial moisture level and whether vacuum or desiccant drying is used.

Processing Methods

The successful processing of PA6 and PA66 requires strict adherence to specific protocols, primarily due to their hygroscopic nature and thermal sensitivity. Pre-drying is non-negotiable; insufficient drying leads to hydrolysis during melt processing, causing molecular weight degradation, surface defects, and compromised mechanical properties. As noted, drying at 80–100 °C for several hours is standard practice to achieve a moisture content below 0.1%.

For injection molding, the barrel temperature profile must be carefully controlled. Typical melt temperatures for PA6 range from 220–280 °C, while PA66 requires higher temperatures, generally between 250–290 °C, to ensure complete melting. Glass fiber-reinforced grades may require temperatures at the upper end of these ranges. Mold temperature plays a critical role in determining crystallinity and, consequently, the final part properties. A mold temperature of 60–100 °C is recommended for PA6, while PA66 benefits from a range of 40–120 °C, with higher temperatures (e.g., 80–100 °C) preferred for achieving optimal surface finish and dimensional stability. Injection pressure is typically high, ranging from 100–180 MPa, to fill complex molds rapidly before the material solidifies. High injection speeds are generally used, although they may be reduced for reinforced grades to minimize fiber breakage. Gate design is crucial; gate diameters should be no smaller than 0.5 times the wall thickness to prevent excessive shear heating and premature freezing.

Extrusion processing is employed for manufacturing continuous profiles such as sheets, rods, tubes, and fibers. The process parameters are similar to injection molding, with precise control over the temperature gradient along the extruder barrel and the die temperature. Cooling must be carefully managed to avoid warpage and internal stresses. Special considerations apply to modified grades: glass fiber-reinforced compounds require hardened screw and barrel components to resist wear, flame-retardant variants need lower processing temperatures to prevent additive decomposition, and regrind usage should be limited to $\leq 10\%$ to maintain consistent quality.

Typical Applications

The distinct property profiles of PA6 and PA66 dictate their application in diverse industrial sectors. In the automotive industry, both materials are indispensable. PA6 is commonly used for intake manifolds, engine covers, oil pans, radiator end tanks, cooling fans, door handles, and interior gears. Its good balance of toughness and processability makes it suitable for these components. PA66, with its superior heat resistance, is favored for more demanding under-

the-hood applications such as fuel line connectors, thermostat housings, transmission parts, and electric power steering components. Both are used in structural parts, connectors, and battery systems for electric vehicles.

In the electrical and electronics sector, their excellent electrical insulation properties and flame retardancy are paramount. PA6 and PA66 are used for connectors, sockets, circuit breakers, switchgear, coil bobbins, and insulating caps. PA66 is often preferred for high-temperature soldering processes like SMT due to its higher melting point. In industrial machinery, their wear resistance and strength make them ideal for gears, bearings, bushings, rollers, pump impellers, valves, and conveyor components. The self-lubricating nature of nylon reduces the need for external lubrication in many applications.

Both polymers find extensive use in consumer goods and sports equipment. PA6 is used in textiles, zippers, toothbrush bristles, and fishing lines. PA66 is found in durable items like luggage wheels, ski bindings, bicycle components, and tool housings. Furthermore, both PA6 and PA66 are increasingly used in additive manufacturing (3D printing), particularly in fused deposition modeling (FDM) and selective laser sintering (SLS), for producing prototypes and functional parts requiring high strength and thermal resistance. Their versatility continues to drive innovation in lightweight structures and advanced composite applications.