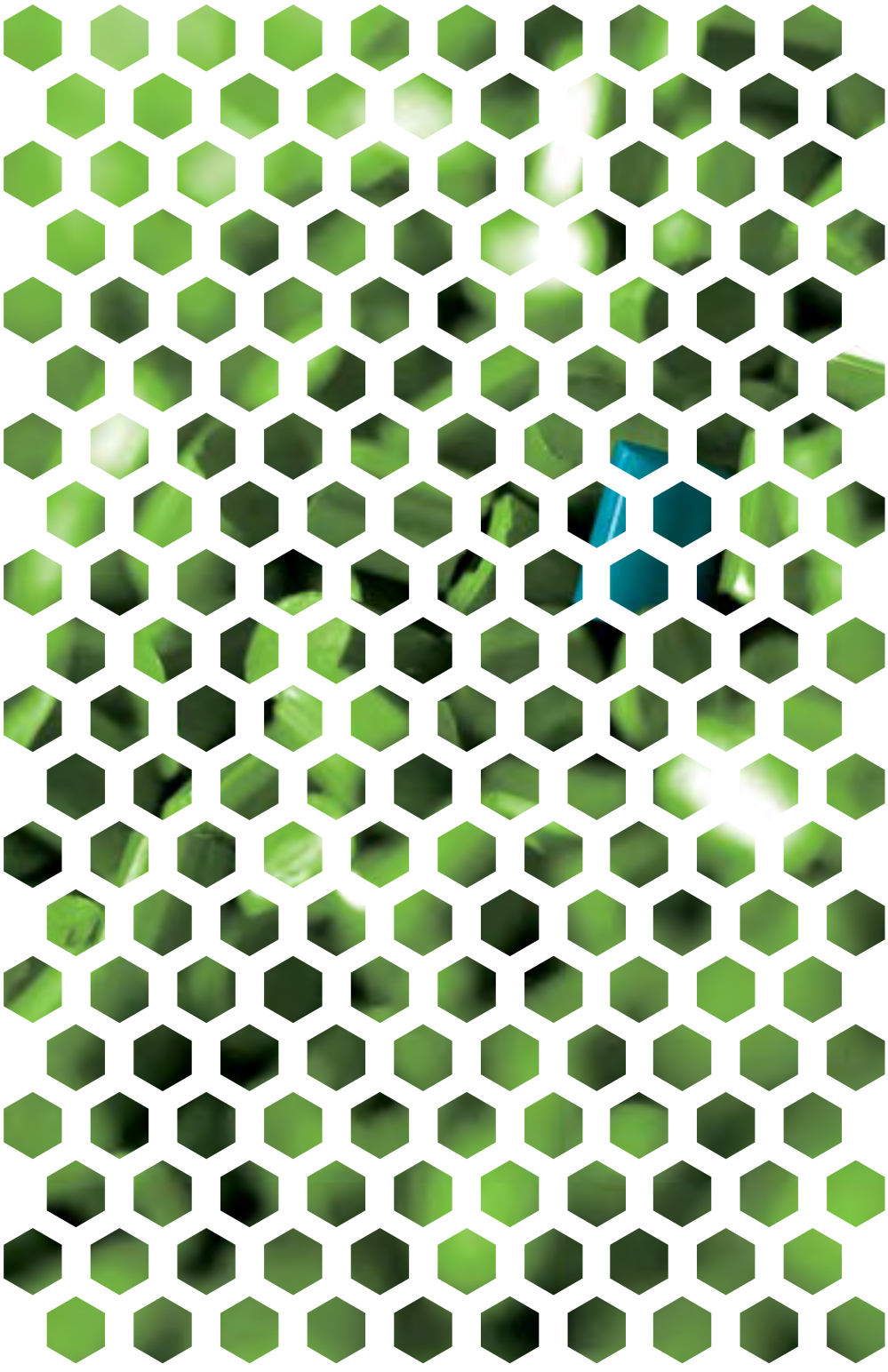


RADICI GROUP
For Sustainability

RADILON® D

Polyamide 6.10 made with 64% renewable source polymer

Radici Plastics is now selling a new polyamide 6.10 range of products suitable for injection moulding and extrusion.

These products, made with 64% renewable source materials, are polymerized from hexamethylenediamine and sebacic acid at RadiciGroup Chemicals plants and then compounded at various Radici Plastics production sites located all over the world.

Sebacic acid is a substance of biological origin obtained from castor oil plant (Ricinus communis) seeds. The plant is cultivated, mostly in China and India, in arid environments, and for this reason does not compete with agricultural products for human consumption.

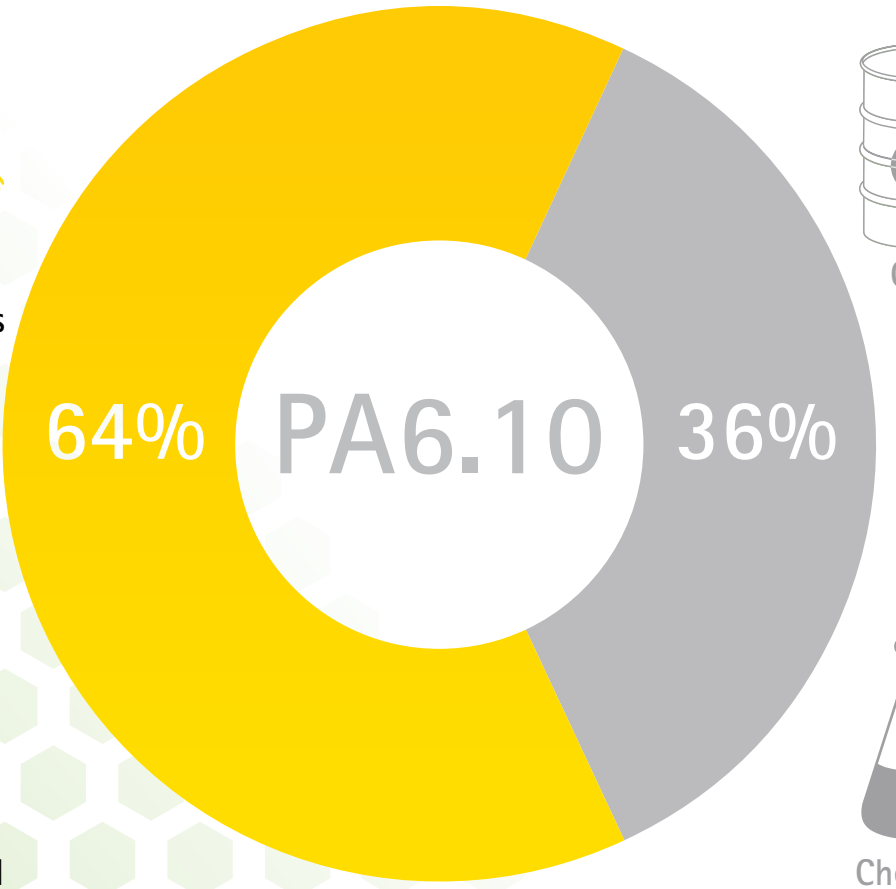
Polyamide 6.10 RadiciGroup's products are made with 64% renewable source materials.

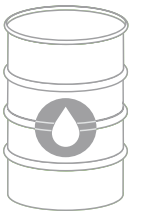
From renewable sources

With low CO_2 emissions

From non-food and non-intensive farming

Ricinus Communis





Crude Oil

Chemical Treatement

Chemical Treatement

Fig.1 - Castor oil seeds used to make sebacic acid, one of the raw materials in the production of PA6.10

Fig.2 - Castor oil plant (Ricinus communis)

PROPERTIES COMPARISON

Radilon® D polyamide 6.10 is a semi-crystalline polymer suited to highly technical applications. Among its main characteristics are:

- Greater dimensional stability compared to PA6 and PA66, due to less water and moisture uptake
- Higher chemical resistance compared to PA6 and PA66
- Greater resistance at high temperatures than PA12
- Excellent hydrolysis resistance

The following graphs compare some of the important characteristics of Radilon® D, PA11, PA12, PA6.12, PA6 and PA66. The values were obtained for base polymers. Adding modifiers, stabilizers and fillers may change the behaviour of the materials significantly.

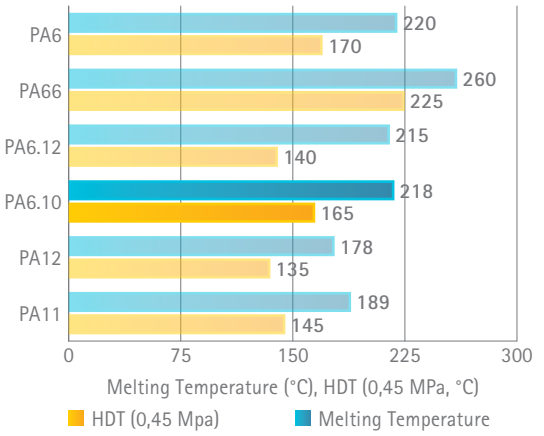


Fig.3 - MELTING TEMPERATURE, HDT

PA6.10 HDT and melting point are higher than the corresponding values for PA11 and PA12. These characteristics can be valuable indicators for determining the usability of a polymer at high temperatures.
The trend in car fuel systems is clearly towards higher temperatures, particularly in diesel engines. A material such as PA6.10 can be a valid alternative, especially for those applications in which PA12 seems to have reached its intrinsic thermal resistance limit.

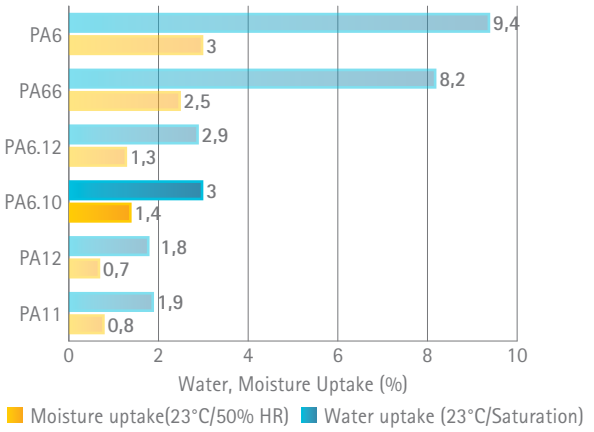


Fig.4 - WATER AND MOISTURE UPTAKE COMPARISON (ISO 62)

PA 6.10 is slightly more hygroscopic compared to both PA11 and PA12. However, the dimensional stability of PA6.10 has proven to be more than adequate for many applications. Moreover, water uptake at saturation is only a third of the value for PA6 and PA66.

RADILON® D GRADES

Radilon® D PA6.10s for injection moulding

Product Name	Product Description	Main Characteristics
Radilon® D HS 105M	PA6.10, unfilled, medium viscosity	Production of injection moulding items. Good chemical resistance and dimensional stability
Radilon® D RV300W (black and natural)	PA6.10, 30% glass-fibre filled, heat stabilized	High rigidity, mechanical and chemical resistance and dimensional stability
Radilon® D RV300RKC	PA6.10, 30% glass-fibre filled, heat and hydrolysis stabilized	High rigidity, mechanical and chemical resistance, hydrolysis resistance and dimensional stability
Radilon® D RV600RKC	PA6.10, 60% glass-fibre filled, heat and hydrolysis stabilized	Very high rigidity, mechanical and chemical resistance, hydrolysis resistance and dimensional stability

Radilon® D PA6.10s for extrusion

Product Name	Product Description	Main Characteristics
Radilon® D 40P50K Radilon® D 40P50W Radilon® D 40P50UK	PA6.10, plasticized, heat stabilized	Translucid, semi-flexible. Suitable for pneumatic pipes and in-tank fuel lines. W version has enhanced heat resistance. UK version has superior UV resistance
Radilon® D 40EP35XK	PA6.10, plasticized, enhanced impact strength, heat stabilized	Opaque, semi-flexible. Suitable for pneumatic pipes
Radilon® D 40EP25ZW	PA6.10, plasticized, heat stabilized, enhanced impact strength even at low temperatures	Semi-flexible. Suitable for air pipes
Radilon® D E35ZW	PA6.10, high impact strength at low temperatures, heat stabilized	Flexible. Suitable for air pipes
Radilon® D 40E75W	PA6.10, good impact strength, heat stabilized	Rigid. Suitable for high pressure air pipes

APPLICATIONS

Radilon® D has been approved for the following applications:

- Pneumatic pipes
- Truck brake air pipes
- Fuel line connectors
- Moulded components when chemical resistance and dimensional stability are required

Additionally, Radici Plastics has developed special materials targeted at applications such as in-tank fuel lines (Fig.7), fittings for the thermosanitary sector (thanks to Radilon® D's excellent glycolysis resistance) and air tubing for high temperature applications, as well as special materials with exceptionally high impact resistance and weather resistance for the sports sector.

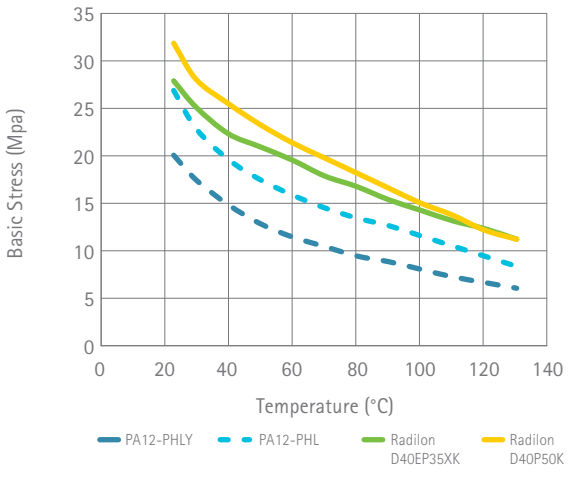


Fig.5 - DIN 73378: BASIC STRESS COMPARISON

Basic stress plotted as a function of operating temperature for two Radilon® D products used for pneumatic tubing.

Application: Pneumatic pipes

Figure 5 shows a graph of the basic stress values taken at temperatures of up to 130°C according to the DIN 73378 standard. In the case of both Radilon® D 40P50K (semi-transparent) and Radilon® D 40EP35XK (opaque) the basic stress values are higher than required by the standard. Both materials are used for pneumatic pipes. The UK version of the same material has higher UV resistance.

Fig.6 - Spiral-shaped pneumatic tubing manufactured using Radilon® D 40P50K. The material is partly transparent and can also be produced in different colours.

Fig.7 - In-tank fuel line made using natural and black Radilon® D 40P50K.

Applications: Truck brake air pipes and brake booster vacuum hoses

For truck air brake pipes (Fig.8), Radici Plastics offers Radilon® D E35ZW and Radilon® D 40EP25ZW in both monolayer and double layer versions. Specifically, semi-flexible Radilon® D E35ZW boasts superior chemical resistance after immersion in water/zinc chloride solutions. This material can also be used as the outer layer in multilayer components.

Fig.8 - Truck brake line tubes made with Radilon® D E35ZW 333 Ner.

Fig.9 - shows the contact zone between a tube and tube connector.

Fig.9 - Air tube with Radilon® D E35ZW 333 Ner outer layer after 200 hours' immersion in 50/50 water/zinc chloride solution at 23°C. As can be seen, the component has withstood immersion totally undamaged thanks to its excellent zinc chloride resistance even in the high stressed connection zone.

The superior performance of Radilon®D E35ZW 333 Ner in zinc chloride solutions opens up new opportunities for PA6.10 in applications where other long-chain polymers have traditionally been used.

The physical and mechanical properties of various Radilon® D air tubes are summarized in the table below. Radici Plastics provides differentiated solutions that can meet the technical specifications of diverse applications.

Property	Unit	D 40P50K Plasticized Translucent	D 40EP35XK Impact Modified Opaque	D 40EP25ZW Impact Modified Opaque	D E35ZW Impact Modified Opaque	D 40E75W Impact Modified Opaque
Density	g/cm³	1,09	1,04	1,04	1,00	1,03
Melting point	°C	215	215	215	220	220
Water uptake (24h-23°C/Saturation)	%	1,1/2,5	1,0/2,3	0,9/2,0	0,8/1,9	-
Yield strength (DAM/RH50)	MPa	42/30	35/30	30	23/19	40
Elongation at break (DAM/RH50)	%	>100/>100	>100/>100	>100/>100	>50/>100	>100
Tensile modulus (DAM/RH50)	MPa	920/550	840/510	580	800/580	1400
Charpy notched impact strength at 23°C (DAM/RH50)	KJ/m²	25/40	73/95	85	80/90	63
Charpy unnotched impact strength at 23°C	KJ/m²	NB	NB	NB	NB	NB
Charpy notched impact strength at -30°C	KJ/m²	6	20	-	75	-
Charpy unnotched impact strength at -30°C	KJ/m²	NB	NB	NB	NB	NB

Applications: Fuel system connectors

The material proposed by Radici Plastics for fuel system connectors (Fig.10) is Radilon® D RV300W 333 Ner, a moulding grade PA6.10. Components manufactured with this material have exhibited excellent dimensional stability and impact resistant characteristics in circulation tests using E10 and E24 fuel and B10 and B30 diesel fuel. The graphs below show how some of the material's mechanical properties change over time after immersion in zinc chloride solutions, after ageing in fuel and after thermal ageing in air.

Fig.10 - FUEL CONNECTOR MADE WITH RADILON® D RV300W 333 NER.

Radilon® D, heat stabilized, 30% GF fullfills the specification of fuel connectors and represents a suitable alternative to PA12-GF30.

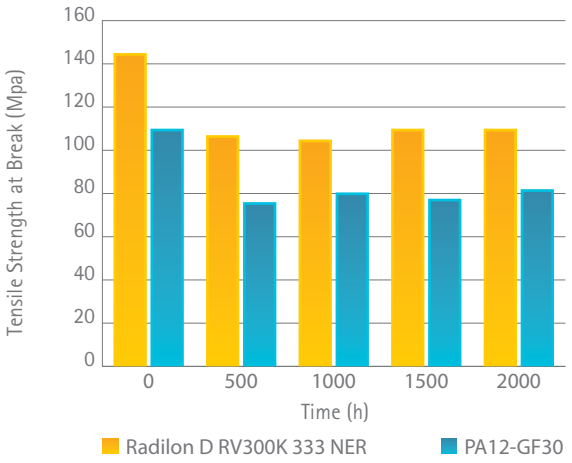


Fig.11 - AGEING IN E24 FUEL AT 90 °C

Change over time in tensile strength after immersion of the materials in fuel containing 24% ethanol. Radilon® D RV300W 333 Ner follows the same trend as PA12-GF30, which has been used to manufacture fuel connectors up to now.

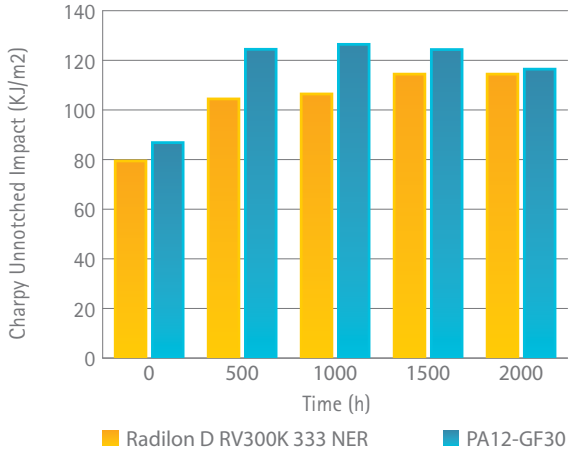


Fig.12 - AGEING IN E24 FUEL AT 90 °C

Change over time in Charpy unnotched impact strength after immersion of the materials in fuel containing 24% ethanol. For Radilon® D RV300W 333 Ner, the graph shows a steady increase with immersion time and, after 2000 hours, Charpy unnotched impact strength is 30% greater than its initial value. On the other hand, for PA12-GF30,after 1000 hours, Charpy unnotched impact strength begins to decrease, which could be a sign of the onset of material degradation. No decline in impact strength is observed for Radilon® D RV300W 333 Ner.

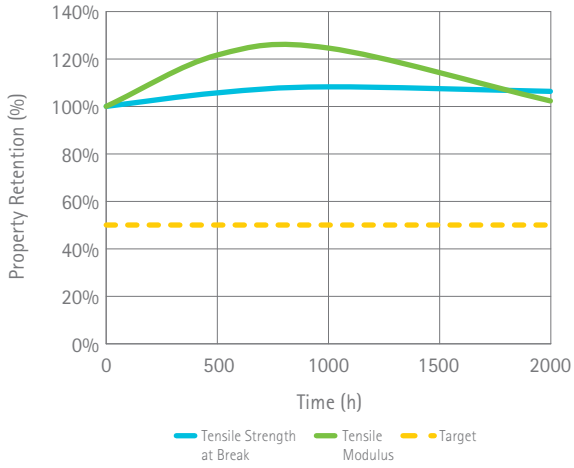


Fig.13 - AGEING IN AIR AT 130°C

Change over time in the mechanical properties of the materials after ageing of up to 2000 hours.
After 2000 hours, Radilon® D RV300W 333 Ner shows no decline in either tensile strength at break or tensile deformation at break compared to the initial values. This product, which is heat stabilized to ensure component integrity against deterioration resulting from thermal ageing, is well within the requirement set forth in many technical specifications that the loss in mechanical properties be no greater than 50%.

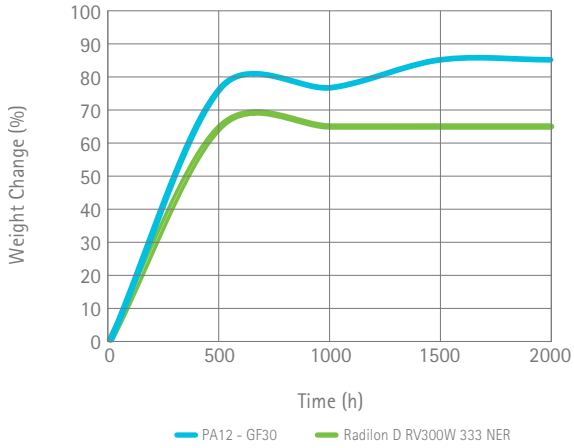


Fig.14 - AGEING IN E24 FUEL AT 90 °C

Weight change over time after immersion of the materials in gasoline containing 24% ethanol.
The graph shows that, after 2000 hours of immersion, the change in weight for Radilon® D RV300W 333 Ner is 2% less than for PA12-GF30. This result shows that Radilon® D has greater dimensional stability.

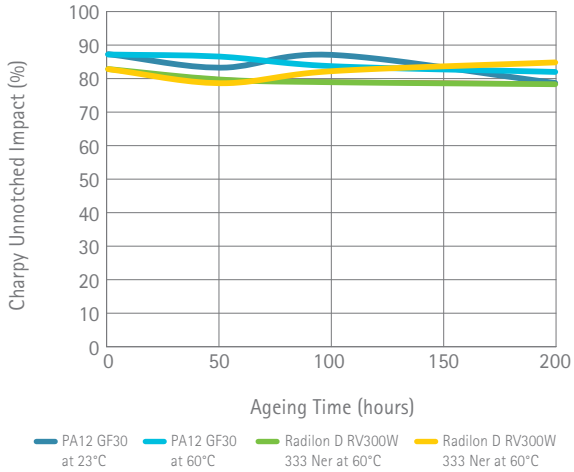


Fig.15 - AGEING IN A 50/50 WATER/ZINC CHLORIDE SOLUTION AT 23°C AND 60°C

The graphs demonstrate that, after ageing in a 50/50 water/zinc chloride solution at 23°and 60°C, there is no significant change in the Charpy unnotched impact strength of Radilon® D RV300W 333 Ner. These results confirm the excellent chemical resistance of Radilon® D compared to PA12.

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