TECHNICAL DATA SHEET

# Roboze Carbon PA PRO

## Overview

Polyamides (PA) are polymers characterized by repeating units (monomers) linked by amide bonds (CO-NH), on which many properties of this type of compound depend. PAs belong to the category of semi-crystalline polymers, i.e., polymers in which the macromolecular chains in the solid state tend to arrange themselves in crystalline regions known as "crystallites". The orderly distribution of the polymer chains is ensured by interactions between the amino group of one chain and the carboxyl group of the adjacent macromolecule.

Roboze's Carbon PA PRO is based on a PA 6 reinforced with carbon fibers. The matrix has been engineered to minimize the melting temperature (234 °C) of the crystalline phase and, thus, reduce the extrusion temperature, enabling easier material processing.

The addition of chopped carbon fibers results in a composite material with high mechanical strength, stiffness, and thermal resistance. Furthermore, the polyamide matrix offers high toughness at low temperatures as well as easy processing.

Carbon PA PRO has low moisture absorption rate, as well as low-warpage and high dimensional stability. In addition, it offers good resistance to a variety of hydrocarbons, such as gasoline, diesel, ethers, and esters.

## Applications

Carbon PA PRO performs best in high mechanical stress applications such as motorsport where it has been successfully used in spoilers and other aerodynamic parts. Its outstanding properties also make it an excellent material for manufacturing structural components in aviation such as frames for drones. Furthermore, it finds many uses in the manufacturing industry, for example for support frames in robotic production lines and, particularly when combined with the design freedom of 3D printing, for the manufacturing of tooling such as centering devices and gripping fingers.

## Design phase

The preparation of the samples and the execution of the individual tests followed the guidelines imposed by the associated regulations. Analyses on the relevant samples were carried out by an accredited, independent and impartial third-party laboratory.[1]

[1] Although data measured in a controlled environment can provide an indication of the chemical/physical and mechanical properties of the material and thus enable comparison between different materials, the results of these tests may not be the same as those observed in the final component.

This phenomenon may be caused by the presence of geometric features or manufacturing conditions that may contribute to modifying the material behaviour. Furthermore, the properties of polymeric materials are a function of both temperature and environmental factors (solar radiation, humidity, etc.), which is why the effect of these variables should also be considered during the design phase, both in the case of short-term and long-term exposure. In view of the above, it is recommended that a prototype be made in advance during the design phase to empirically verify its properties in the operating conditions required by the specific application.

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## Printing procedure information

Specimens were manufactured on a Roboze ARGO 500 using filament with a diameter of 1.75 ± 0.05 mm and extruded through a 0.6 mm diameter nozzle. The material was dried at 90 °C for 12 hours in HT Dryer.

The printing parameters were maximized in the range as reported below in order to obtain the best compromise between mechanical properties, surface finishing and the maximum value of specific gravity in a standard ASTM D638 Type IV sample:

- Chamber Temperature = 90°C
- Extrusion Temperature = 260°C - 280°C
- Printing speed = 1800 mm/min - 3600 mm/min
- Layer height = 0.25 mm - 0.30 mm

It is possible to identify three different orientations of the printed samples, named as follows:

- Flat (or XY)
- On Edge (or XZ)
- Upright (or ZX)

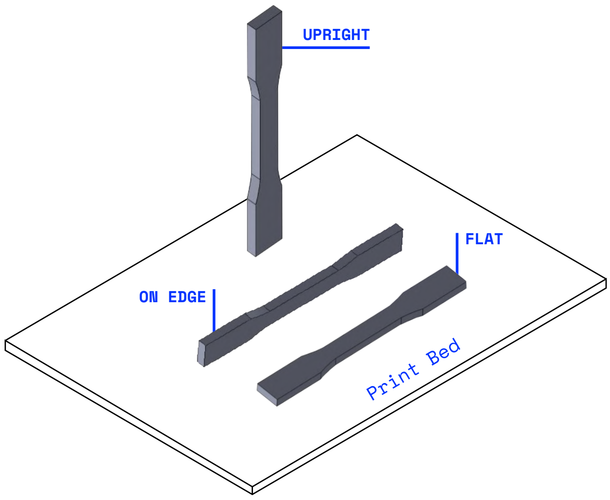


*Figure 1 Example of On Edge, Upright and Flat orientation on the building plate*

Five samples in XY and XZ - direction were printed in one process to characterize the material. As for the ZX - oriented samples, walls with dimensions 120x3.2x60 mm were printed and, subsequently, milled to obtain two specimens per wall with dimensions defined by the standard. This peculiar procedure in ZX specimens allowed to minimize the influence of a post-processing directly on the samples and, therefore, on their mechanical properties. The infill orientation for XY specimens was ± 45°, conversely, for XZ and ZX-oriented samples the infill was at 0°.
At the end of the printing process, the XY and XZ-oriented samples were subjected to the phase of manual removal step of the support structures. The results of the mechanical properties show the average value of the five samples and their standard deviation.
Before testing the material, the samples were conditioned in an oven for 4 hours at 90°C and tested once room temperature is reached.

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## Mechanical Properties: test parameters

### Tensile Properties

The ASTM D638 standard was used to perform tests with a speed of 1 mm/min to calculate the tensile modulus and, subsequently, at 50 mm/min until the samples are broken. It is important to consider that the results of the tensile tests can be influenced by the used parameters.

The curve and the table below report the stress-strain curves and the value recorded during the tensile tests, respectively. The fracture surfaces of the samples broken during the tests are also shown in the figure.

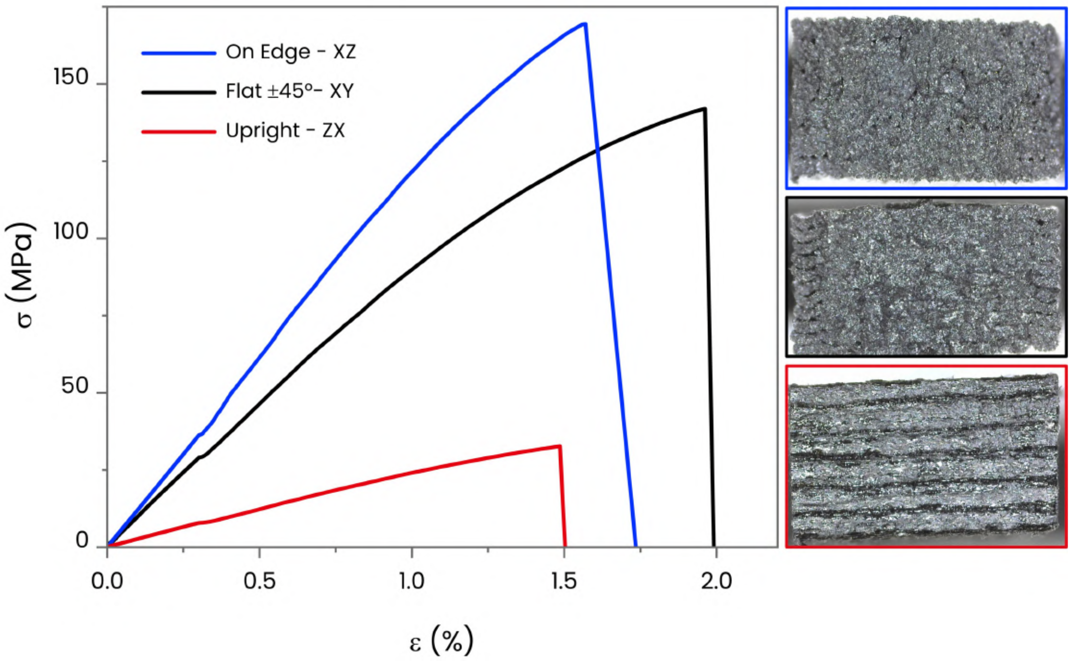


*Figure 2: Comparison between tensile test behavior of Carbon PA PRO samples built in different orientations and fracture surface of samples (blue:on edge, black: flat, red: upright)*

*Table 1 Results of tensile properties of Roboze Carbon PA PRO at 25°C at different specimen orientations*

| TENSILE TEST ASTM D638 | UNITS | ORIENTATION | | |
|---|---|---|---|---|
| | | XZ | XY ±45° | ZX |
| Tensile Strength | MPa | 171 ± 5 | 142 ± 1.7 | 34 ± 2 |
| Young's Modulus | GPa | 13 ± 0.8 | 8.7 ± 0.2 | 2.6 ± 0.4 |
| Elongation at maximum load | % | 1.58 ± 0.08 | 2.2 ± 0.1 | 1.6 ± 0.2 |

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# Roboze Carbon PA PRO PRO

## Summary of Roboze Carbon PA PRO properties

### MECHANICAL PROPERTIES

| PROPERTY | OPERATING CONDITIONS | UNITS | ORIENTATION | | | TEST METHOD |
|---|---|---|---|---|---|---|
| | | | XZ | XY ± 45° | ZX | |
| Tensile Strength | 25 °C | MPa | 171 ± 5 | 142 ± 1.7 | 34 ± 2 | ASTM D638, type IV |
| Young's Modulus | 25 °C | GPa | 13 ± 0.8 | 8.7 ± 0.2 | 2.6 ± 0.4 | ASTM D638, type IV |
| Elongation at maximum load | 25 °C | % | 1.58 ± 0.08 | 2.2 ± 0.1 | 1.6 ± 0.2 | ASTM D638, type IV |

### PHYSICAL PROPERTIES

| PROPERTY | OPERATING CONDITIONS | UNITS | VALUE | TEST METHOD |
|---|---|---|---|---|
| Specific gravity | | g/cm³ | 1.232 | ISO 1183-1 |
| Glass transition temperature ($T_g$) | 20 °C/min heating and cooling rate, in air | °C | 70 | ISO 11357-2 DSC |
| Crystallization temperature ($T_c$) | 20 °C/min heating and cooling rate, in air | °C | 180 | ISO 11357-3 DSC |
| Melting point ($T_m$) | 20 °C/min heating and cooling rate, in air | °C | 234 | ISO 11357-3 DSC |
| Melt volume flow rate | 275 °C, 5 kg | cm³/10 min | 42.2 | ISO 1133 |
| Reinforcing phase (carbon fibers) | | % by weight | 15 | |
| Colour | | | Black | |

## CHANGELOG

| FILE NAME | REVISION DATE | UPGRADES |
|---|---|---|
| Carbon PA PRO – Technical datasheet – ENG[02] | 28.04.2023 | 1. Printing procedure information<br>2. Tensile test results |