TECHNICAL DATA SHEET

Roboze Carbon PEEK

Overview

Carbon PEEK is a composite material with a PEEK matrix reinforced with 20% chopped carbon fibers. These greatly improve the compressive strength, stiffness, and load capacity of the composite compared to virgin PEEK, vastly increasing the breadth of the applications possible.

Carbon PEEK has a higher thermal and electrical conductivity than neat PEEK and therefore reduces its rate of thermal expansion with a lower coefficient of linear thermal expansion (CLTE). Together with the chemical resistance typical of semi-crystalline polymers, it offers excellent mechanical properties and stability.

Thanks to the addition of carbon fibers, Carbon PEEK also offers a lower dry friction coefficient because of the higher thermal conductivity of the particles. It is very resistant to hydrolysis in boiling water and superheated steam, as well as to organics, acids, and bases.
Carbon PEEK is considered among the strongest of all thermoplastics at room temperature thanks to its superlative properties that, together with its excellent wear and abrasion resistance, make it ideal for the substitution of metals in extreme environments.

Applications

Carbon PEEK can be used both for functional prototypes and for end-use parts thanks to its very high mechanical properties.

It is used in a wide range of industries, from aerospace and defense to automotive, from oil and gas to manufacturing to motorsport. Its substantial durability makes it a common choice for demanding environments. Typical applications include bearing retainers, bushings, oil and gas processing equipment, seals, thrust washers, pump and compressor components, aircraft hardware and fasteners, aircraft mechanical components.

Thanks to its excellent property profile, which includes high toughness, continuous service temperature, and high melting point and glass transition temperature, it is the perfect candidate for metal replacement applications, which result in important weight savings, a fact that is particularly relevant in industries such as aerospace and defense.

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 defects that may contribute to modifying the material behaviour. Thermal history, crystallinity variations, alteration of the distribution, dispersion, and orientation of the reinforcing phase are other factors that could induce the above phenomenon. 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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Manufacturing Process

Specimens were manufactured on a Roboze ARGO 500 fed with a filament with a diameter of 1.75 ± 0.05 mm. This thermoplastic filament was subsequently extruded through a 0.6 mm diameter nozzle. To minimize the concentration of water molecules adsorbed and absorbed by the filament due to exposure to the atmospheric environment, before starting the printing process, Carbon PEEK spools were subjected to a drying cycle at a temperature of 120 °C for 8 hours in HT Dryer.

The temperature of the working chamber was set to 160 °C. To allow isothermal conditions within the hot chamber, 2 hours was waited before starting the printing process.

Printing conditions for the data in the following tables were:

- Chamber Temperature = 160 °C
- Extrusion Temperature = 440 °C
- Printing speed = 2100 mm/min
- Layer height = 0.27 mm
- Infill percentage= 100%
- 2 Shells

At the end of the printing process the support structures were manually removed.

The additive manufacturing technology produces intrinsically anisotropic components. As the orientation of the component on the printing plate changes, so do both the properties of the final printed part and the productivity of the printing process. Keeping in mind what has been written above, it is possible to identify three different orientations on the building plate that are named as follows:

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

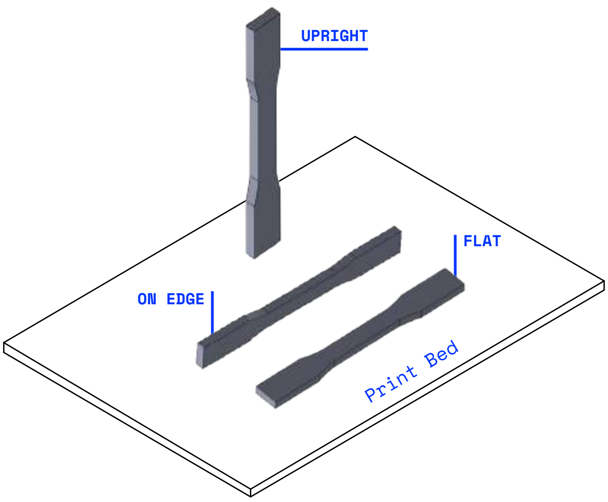

Figure 1 Example of On Edge, Upright and Flat orientation on the building plate

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Carbon PEEK properties Summary

MECHANICAL PROPERTIES

PROPERTY	OPERATING CONDITIONS	UNITS	ORIENTATION		TEST METHOD
			XZ	ZX	
Tensile Strength	25 °C	MPa	125	55	ASTM D638, type IV
Young's Modulus	25 °C	GPa	10.1	3.7	ASTM D638, type IV
Elongation at break	25 °C	%	2	2	ASTM D638, type IV

PHYSICAL PROPERTIES

PROPERTY	OPERATING CONDITIONS	UNITS	VALUE	TEST METHOD
Specific gravity		g/cm^3	1.41	ASTM D792
Glass transition temperature (T_g)	20 °C/min heating and cooling rate, in air	°C	149	Differential Scanning Calorimetry (DSC)
Melting point (T_m)	20 °C/min heating and cooling rate, in air	°C	341	Differential Scanning Calorimetry (DSC)
Reinforcing phase (carbon fibers)		% by weight	20	
Colour			Black opaque	

The information may come from the raw material, the semi-finished product, or an estimate.
Specific individual tests are recommended according to the conditions required for final implementation

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Mechanical Properties

Tensile Properties

The tensile test is a destructive test useful to characterize the properties of materials when subjected to uniaxial tensile loads. A specimen of standard dimensions, having a "dogbone" geometry, is clamped by means of appropriate clamps to two crossbeams.

The movable crossbeam can move upwards, thus bringing the specimen into a tensile state. Once the displacement speed of the crossbar has been set, the load applied, and the deformation undergone by the sample are monitored during the test.

In output the system is able to provide a Cartesian graph where on the ordinates is represented the stress (σ), i.e. the ratio between the force applied to move the mobile crosshead at constant speed and the minimum section of the "dogbone" test specimen; while the abscissae report the strain (ε), i.e. the percentage ratio between the variation of length of the test specimen with respect to its initial dimensions ($\Delta\ell$)) and its nominal length before the start of the test (ℓ_0).

The stress-strain curve will be a function of the nature of the material. The characteristic parameters that can be derived from this curve are: tensile strength (σ_M), Young's modulus (E) and elongation at break (ε_0).

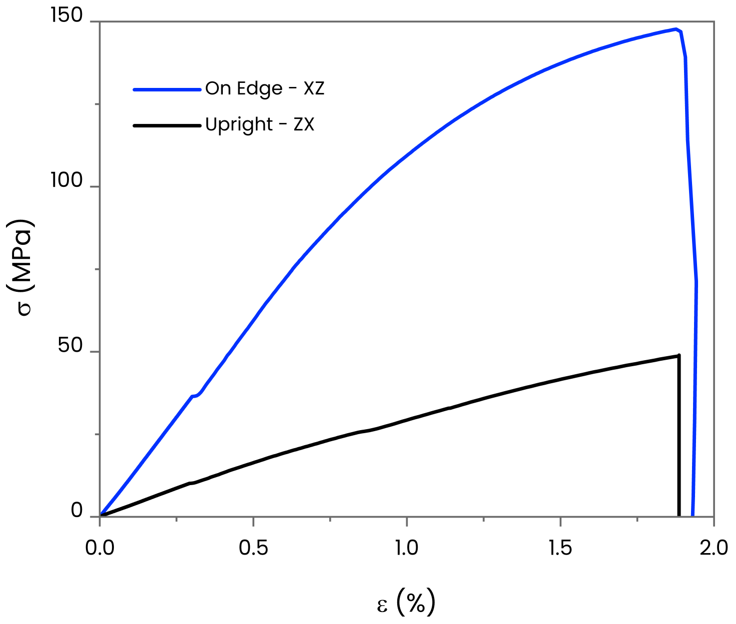

Figure 2: Comparison between tensile test behaviour of Carbon PEEK samples built in different orientations

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The initial section of the curve shows a region of linear elastic deformation. In this region (also called the Hookean region of the material), the material undergoes an instantaneous and reversible strain that is linearly dependent on the applied stress.

The angular coefficient of the tangent line to the linear elastic region is defined as Young's Modulus, which is the constant of proportionality between the strain undergone by the material and the applied stress. Young's modulus is generally measured from the stresses at 0.05 % and 0.25 % strain. It should be noted that components manufactured by additive manufacturing have anisotropic mechanical properties therefore, particularly with very complex geometries, it can be difficult to maximize the mechanical response. Typically the best practice is to identify the main load direction and orient the part in relation to this.

The samples were characterized using the ASTM D638 standard. ZX-oriented specimens were milled from a 120x3.2x60 mm plate to evaluate inter-layer adhesion properties with minimal interference from spurious phenomena. A speed of 1 mm/min was used to calculate the tensile modulus, thereafter the speed was increased up to 50 mm/min until the specimen failed. It should be noted that results of tensile testing are a function of test speed, therefore for a proper comparison between different materials it is important to know in advance the speed at which the test was performed.

Table 1: Tensile properties of Carbon PEEK measured at 25°C for different specimen orientations

PROPERTY	OPERATING CONDITIONS	UNITS	ORIENTATION		TEST METHOD
			XZ	ZX	
Tensile strength	25 °C	MPa	125	55	ASTM D638, type IV
Young’s modulus	25 °C	GPa	10.1	3.7	ASTM D638, type IV
Elongation at break	25 °C	%	2	2	ASTM D638, type IV