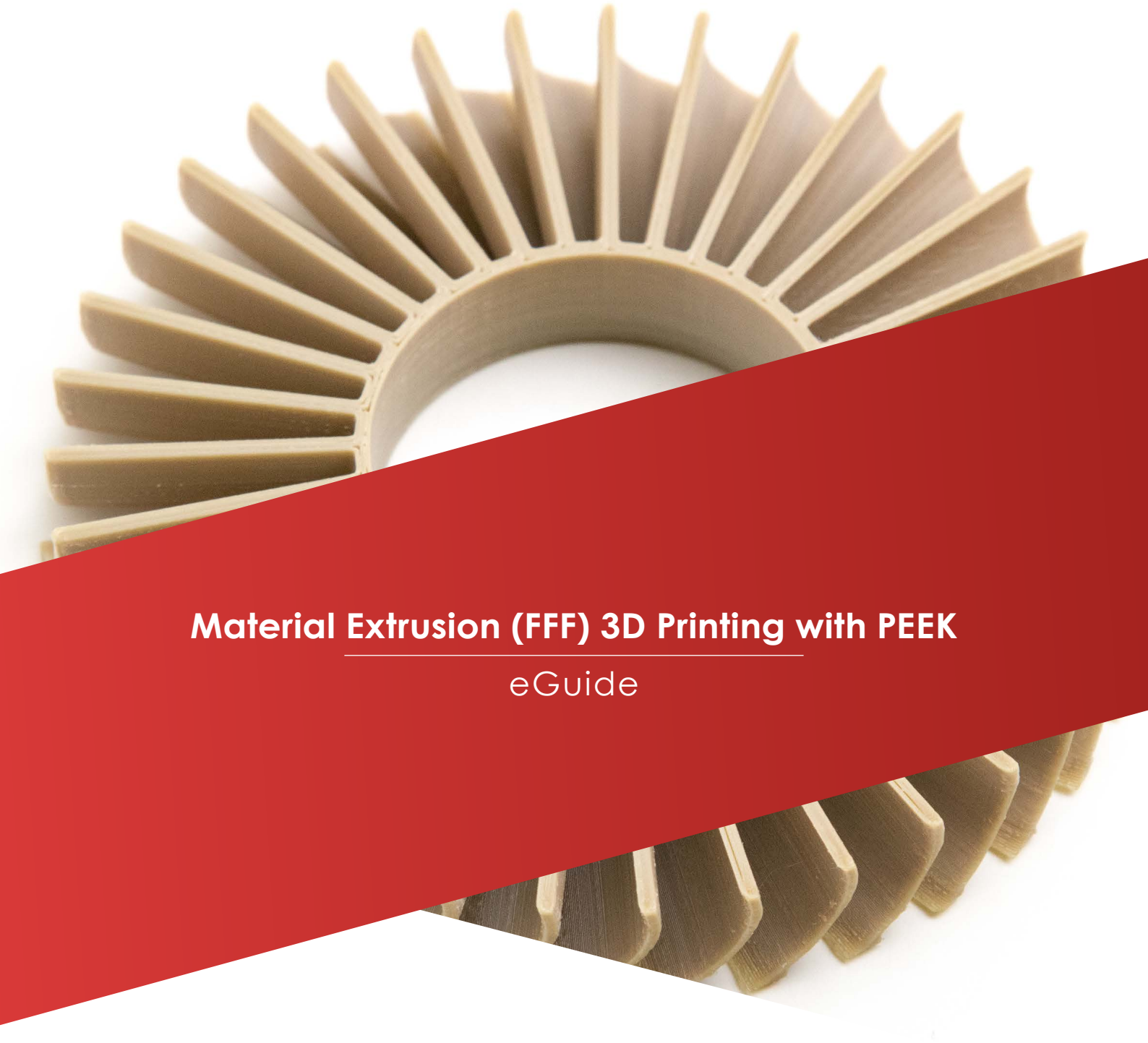

Material Extrusion (FFF) 3D Printing with PEEK

eGuide

Apium
Additive Technologies GmbH

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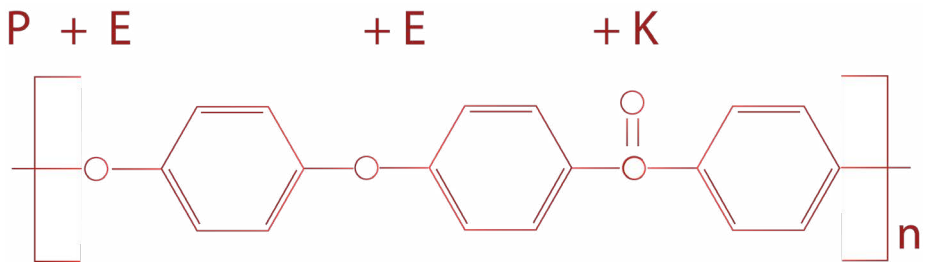
Selection of PEEK Filament

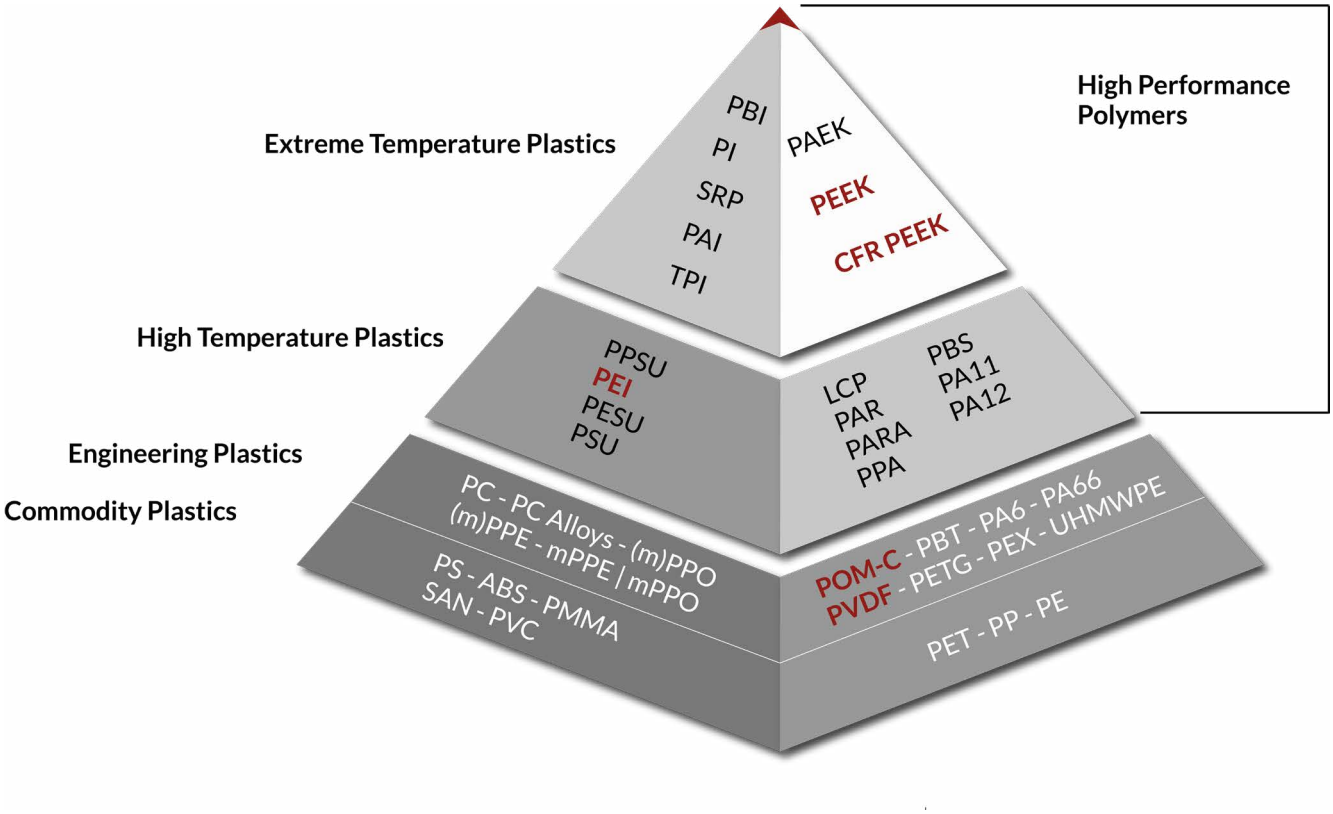
◊ What is PEEK?

Polyetheretherketone (PEEK) is a semi-crystalline thermoplastic polymer belonging to the PAEK family. Other members of this family are PEK and PEKK. As the chemical structure for PEEK indicates below, a sequence of ether (E) and ketone (K) linkages are positioned on a PEEK backbone making this polymer unique in its own right.

PEEK is the most commercially visible member of the PAEK family. It is typically colourless, structurally stable at over a wide temperature range (from -196 °C to 260 °C), exhibits chemical resistance, shows appreciable wear resistance, it is bio-compatibility and its melt can be processed in a straight forward manner. Under tensile loading conditions its mechanical properties are superior to that of thermosets.



PEEK has a glass transition temperature (Tg) of 146 °C and a melting temperature (Tm) of 338 °C. At temperatures of between 575 °C and 580 °C it undergoes an onset of thermal decomposition. PEEK's unique combination of mechanical, thermal and chemical properties makes it suitable for its application in technically demanding engineering scenarios.



Semi-crystalline polymeric materials such as PEEK are composed of regions which are rich in amorphous phase and those that are rich in crystalline phase. The crystallization process in such materials occurs by different routes:

(a) cooling from the melt

(b) by mechanical stretching

(c) by solvent evaporation.

Typically the amorphous phase is optically translucent, more ductile and mechanically less stiff than the crystalline phase. Thus under controlled processing conditions the different phases of the PEEK material can be manipulated to fit certain application requirements.

◊ PEEK Filament Properties

The conversion of raw PEEK granules into filament form involves thermos-mechanical processes which can significantly influence the transfer of the basic physical properties of the granular material to the filament material. A great deal of extrusions experience is therefore needed to ensure that these basic properties are preserved in the filament.

It goes without saying that the properties of the filament, especially its dimensional tolerances, are strictly specified for processing using filament based Material Extrusion 3D printing technology. Filaments which show even marginal differences in diameter along their length can easily produce severe processing challenges notably the blockage of nozzles resulting from highly uneven extrusion and discharge of the PEEK melt during the 3D printing process. Therefore the ability to guarantee that the filament meets both chemical and physical requirements is an essential qualification aspect of PEEK 3D print processing.

Apium's PEEK filaments; Apium PEEK 450 Natural and Apium PEEK 450 Black, are produced under such standards thus making it possible to fulfil the following attributes:

Ease of Processing

These filaments are made from the grade of PEEK material which is especially suitable for extrusion purposes and has processing properties optimum for handling on Apium P Series 3D printers.

Purity

The high purity filament is exceptionally of low outgassing.

High Temperature Performance

PEEK has a heat deflection temperature of 152 °C ensuring its structural stability at the operating temperatures of most conventional engineering applications. Its operating range lies from -196 °C to 260 °C.

Low Smoke and Toxic Gas Emission

Under conditions of thermal combustion, pure PEEK is inherently flame resistant, demonstrating properties of a retardant whilst producing combustion gases of markedly low toxicity.

Chemical Resistance

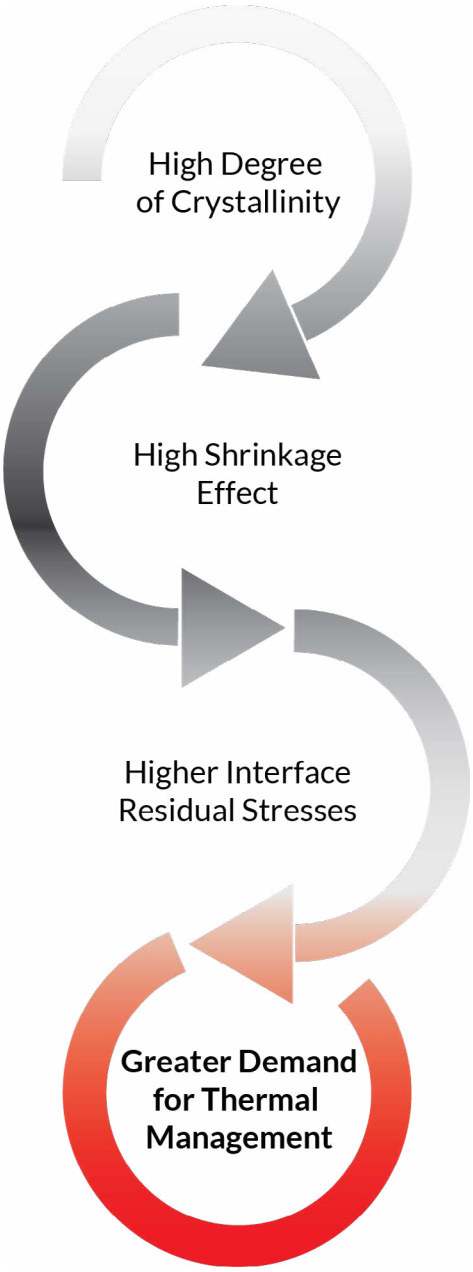
The 3D printed parts from Apium PEEK 450 filaments are able to withstand a wide range of organic solvents, hydrocarbons, acids and bases.

Mechanical Strength

Parts which are 3D printed from Apium PEEK filaments achieve the highest mechanical strength and stiffness acceptable for this material.

◊ Thermal Management Requirements

There is a need to fully understand the behaviour of materials under any processing regime. This is especially true for semi-crystalline high-performance polymeric materials such as PEEK. This is as a result of the combined influence of the chemistry, thermal properties and microstructure of PEEK. Because temperature plays a cardinal role in extrusion based processing scenarios, it is important to be aware of the thermal management requirements of such classes of materials drawing a clear distinction with commodity polymers and amorphous polymers where the process control rigours of thermo-mechanical influences during Material Extrusion (FFF) 3D Printing is markedly less.



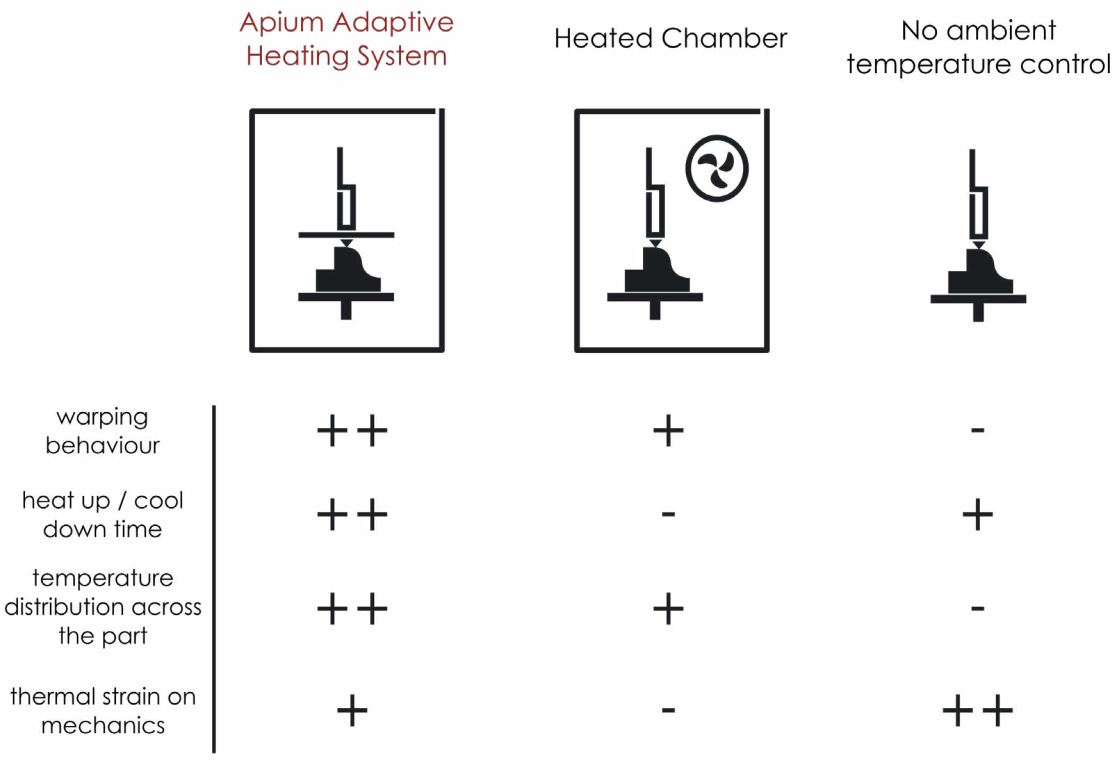
Though crystallinity itself poses a processing challenge, the impact of the crystallization process; typically initiated in the melt, on the dimensional outcome of printed part can be technically unacceptable since warping and other shrinkage associated effects are created.

The printed part, of course, attempts at accommodating these structural effects leading consequently to the creation of internal stresses in the part. This results either to the build-up of residual stresses or the formation of cracks in the part if the magnitude of the internal stresses exceed the nominal strength of the printed part. As a result of the nature of the part build-up (layer by layer) during 3D printing, structural failure in the part often is confined to interfaces or physical boundaries of layers.

These different effects invariably conspire to place a necessary demand for thermal management during the 3D printing process to ensure that parts which meet design specifications are fabricated.

To achieve a desirable printing outcome, process controls are therefore necessary. On Apium's P Series 3D printers, the level of process control allows for the fabrication of PEEK parts where amorphous regions as well as crystalline regions can be preferentially introduced at defined locations in the parts.

◊ Comparison of Available Material Extrusion 3D Printing Temperature Management Systems



Comparison of Temperature Control Technologies (++ Best performance, - lowest performance)

◊ Adaptive Heating System

Patented by Apium Additive Technologies GmbH, the Adaptive Heating System manages the temperature-associated influences on the processed material making it possible to fabricate high quality parts.

The Adaptive Heating System technology provides an advanced temperature control, which makes material-specific adjustments on the printer possible and aims at achieving the best temperature distribution possible in the printed part, depending on part geometry.

This is a feature lacking in other commercially available Material Extrusion 3D printing technologies. The thermal management realizable from the Apium Adaptive Heating System can control the degree of crystallinity in polymers, which exhibit crystalline properties. This tool also improves the process quality as it provides shorter heat up, cool down times, and ideally eliminates warping of 3D printed parts.

For further information and questions about PEEK 3D Printing, please contact our experts.

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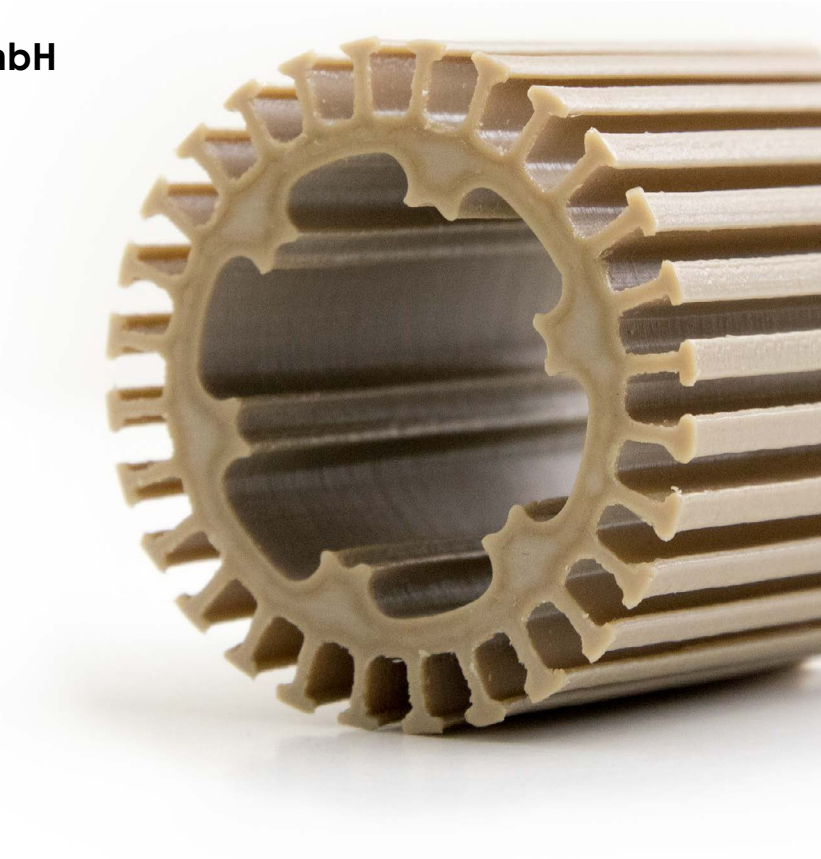

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