TOOLING MATERIAL BRIEF

FDM Nylon 12CF

BACKGROUND

When designing tooling for industrial uses, the natural tendency is to use aluminum or an alternative metal alloy. This is because the mechanical properties tend to be well above the requirements of many applications and do not need to be questioned. However, in many instances, thermoplastics have the required strength to work, but lack the rigidity to perform the task.

This is where composite materials come into play. Adding a reinforcement to a base polymer can drastically change the mechanical properties to the point that metal replacement becomes a reality for many tooling uses. To accomplish this task, Stratasys developed FDM Nylon 12CF™ for the Fortus 450mc™ 3D Printers.

WHAT IT IS

Starting with our proven FDM Nylon 12™ blend, Stratasys added chopped carbon fiber reinforcement, 35% by weight, to enhance the mechanical properties of the polymer. The result is a material with the highest stiffness-to-weight ratio of any FDM® material currently produced, and a tensile strength on par with other high-performance FDM materials.

BUILD CONSIDERATIONS

- **Anisotropy -** Anisotropy is the definition of a material or structure having directionally dependent properties. For FDM Nylon 12CF, it means the increase in strength is directly tied to the orientation of the part during the build. The extrusion process preferentially aligns the carbon fibers in the direction of extrusion, so the major gains are in the XY orientation. There isn't any loss of strength transverse to the layers in the Z direction, but there isn't any significant improvement either.

  Strength in that direction can be expected to be very similar to that of unfilled FDM Nylon 12 material. Based on this, the areas of the part with the highest load requirements should have an orientation parallel to the build platform to take full advantage of the material's increased strength and stiffness.

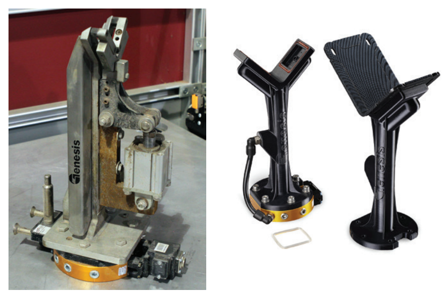
- **Surface quality** - The Z direction surface finish can be very nice directly out of the printer, but due to the addition of the fibers, the XY surface finish may not be as consistent as other FDM materials. With a little post-processing, however, the surface finish can be brought to a very high-quality level. Post-processing techniques depend on the individual requirement, but range from basic hand sanding to bead blasting, or to vibratory tumbling and beyond.

- **Slice heights** - Currently, this material can be built in a 0.01 inch [0.25 mm] slice height. This layer thickness offers a good blend between overall build aesthetics and build-time efficiency.

- **Support Style** - Box supports are recommended on parts with significant amounts of internal geometry. This allows the most efficient removal in the waterworks tanks. All other geometry can be built with traditional sparse or basic supports.

- **Infill styles** - To avoid the increased wear on the printer tip, sparse double-dense infill is not available. The sawtooth infill pattern should be applied using a custom group as an alternative.

- **Sacrificial towers** - A sacrificial tower should always be used when building with FDM Nylon 12CF. This will reduce or remove many of the surface irregularities that occur when the head switches from support to model materials. It is best to choose the full height option for the sacrificial tower.

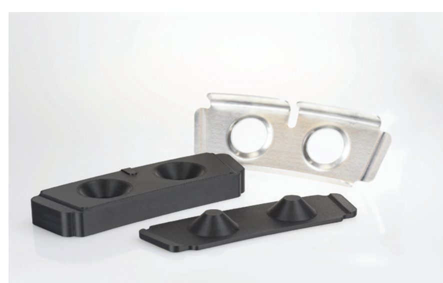


An example of a customer success story from Genesis Systems Group, displaying the transition from a complex, traditional EOAT to a simplified, lighter, FDM component using design-for-additive-manufacturing methodologies.

WHERE IT FITS

- **Robotic end effectors (end-of-arm-tooling)** - Reducing mass at the end of a robotic arm has many positive benefits. Reduced wear and tear is a key consideration, but reduced mass is often overlooked, which offers benefits through a smaller-class, lower-cost robot. FDM Nylon 12CF can be used for many end-effector applications including, but not limited to, pick-and-place, part trimming, grippers, etc.

- **Metal Forming** - One of the major contributors to process variability in sheet metal forming is spring-back of the material being formed. While FDM tooling has been used for sheet metal forming with much success, additional consideration is needed to compensate not only for material spring-back, but



This metal-forming tool is 3D printed using Nylon 12CF material.

also for local tool deformation. FDM Nylon 12CF reduces the compensation requirement due to the significant increase in stiffness. It also has greater wear resistance due to the addition of carbon fiber reinforcement, so it is expected to provide a higher yield compared with tools made from other FDM materials.

- **Jigs / Fixtures** - FDM Nylon 12CF enables users to create production jigs and fixtures for applications where they previously weren't considered, due to material flexibility. With a tensile modulus over 3x higher than the next closest FDM material, users can expect a significant reduction in part deformation from applied loads.
- **Drill guides** - With the large gains in stiffness from the addition of the carbon fiber reinforcement, FDM Nylon 12CF is a great choice for drill guides. This material provides greater rigidity, resulting in better accuracy of the drilled hole. Also, the stiffness allows the fixture to be a conformal surface when the part has inherent flexibility, e.g., light-gauge sheet metal.
- **Bracketry** - Similar to the notes about the use of FDM for jigs and fixtures, lightweight, stiff FDM Nylon 12CF brackets can replace metal brackets in an industrial setting. This is especially beneficial for brackets of moderate to high complexity that would require multiple components or difficult machine setups due to part geometry.

An installation fixture for Eckhart USA used to locate and install an automotive bracket. The FDM tool is lighter and uses steel touchpoints for increased durability.

An example of a drill jig with metal inserts, made with Nylon 12CF.

Custom tooling brackets by Orbital ATK designed for flexibility and rapid response to project requirements. FDM Nylon 12CF provides the necessary strength and stiffness.

MECHANICAL PROPERTIES	TEST METHOD	ENGLISH		METRIC	
		XZ Axis	*ZX Axis*	*XZ Axis*	*ZX Axis*
Tensile Strength, Yield (Type 1, 0.125", 0.2"/min) PSI	ASTM D638	9,190 psi	4,170 psi	63.4 MPa	28.8 MPa
Tensile Modulus (Type 1, 0.125", 0.2"/min) PSI	ASTM D638	1.1 Msi	0.33 Msi	7515 MPa	2300 MPa
Tensile Elongation at Yield (Type 1, 0.125", 0.2"/min) %	ASTM D638	0.9%	1.1%	0.9%	1.1%
Flexural Strength (Method 1, 0.05"/min) PSI	ASTM D790	20,660 psi	8,430 psi	142 MPa	58.1 MPa
Flexural Modulus (Method 1, 0.05"/min) PSI	ASTM D790	1.5 Msi	0.3 Msi	10,620 Mpa	1830 MPa
IZOD Impact, notched (Method A, 23 °C) ft-lbf/in	ASTM D256	1.6 ft-lb/in	0.4 ft-lb/in	85 J/m	21.4 J/m
IZOD Impact, un-notched (Method A, 23 °C) ft-lbf/in	ASTM D256	5.8 ft-lb/in	1.6 ft-lb/in	310 J/m	85 J/m

THERMAL PROPERTIES	TEST METHOD	ENGLISH	METRIC
Heat Deflection (HDT) @ 264 psi	ASTM D648	289 °F	143 °C

ELECTRICAL PROPERTIES	TEST METHOD	VALUE
Volume Resistivity (kOhms)	ASTM D257	5.4E+03 - 3.9E+04
Surface Resistivity (kOhms)	ASTM D257	3.3E+03 - 6.9E+04

OTHER	TEST METHOD	VALUE
Specific Gravity	ASTM D792	1.15

alphacam
SOLUTIONS FOR A 3D WORLD®

alphacam GmbH
Erlenwiesen 16
D-73614 Schorndorf
Tel. +49 (0)7181-92 22-0
info@alphacam.de
www.alphacam.de

alphacam swiss GmbH
Bahnhofstr. 5
CH-9443 Widnau
Tel. +41 (0)71-77 58 24-0
info@alphacam.ch
www.alphacam.ch

alphacam austria GmbH
Handelskai 92, Gate1 / 2. OG / Top A
A-1200 Wien
Tel. +43 (0)1-361 96 00-0
info@alphacam.at
www.alphacam.at

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