

# Vega™

## CARBON FIBER FILLED PEKK MATERIAL

Vega is an ultra high-performance carbon fiber filled PEKK for 3D printing critical aerospace parts on the FX20. Formulated by Markforged engineers and material scientists, it exhibits a smooth matte black surface finish that is excellent for production parts. Vega can be reinforced with continuous fiber to achieve aluminum strength for aerospace components.

Carbon Fiber HT and Carbon Fiber HT-A are specialized variants of Markforged's continuous Carbon Fiber designed for use with Vega and ULTEM™ 9085 Filament<sup>1</sup>. Capable of yielding aluminum strength parts, they can be precisely laid down in a wide variety of geometries.

### Features and benefits

- High heat and FST resistance
- Chemical and solvent resistance
- Low outgassing
- Matte surface finish
- High strength with CF-HT reinforcement



Physical Properties	Unit	Test (ASTM)	Vega XZ Orientation	Test	Carbon Fiber HT (CFR) <sup>2</sup>	Carbon Fiber HT-A (CFR) <sup>2 3</sup>
Tensile Strength	MPa (ksi)	D638	87.6 ± 3.0 (12.7 ± 0.5)	D3039	800 (116)	800 (116)
Tensile Modulus	GPa (ksi)	D638	5.2 ± 0.2 (0.8 ± 0.03)	D3039	69 (10,005)	69 (10,005)
Elongation at Break	%	D638	3.0 ± 0.2	D3039	1.6	1.6
Flexural Strength	MPa (ksi)	D790	140.2 ± 8.4 (20.3 ± 1.2)	D790	439.5 (63.7)	529.7 (76.8)
Flexural Modulus	GPa (ksi)	D790	4.7 ± 0.3 (678.3 ± 0.04)	D790	50.3 (7,291.1)	53.3 (7,730.5)
Flexural Extension at Break	%	D790	5.2 ± 0.5	D790	1.0	1.1
Compressive Strength	MPa	D695	221.3 ± 35.9 (32.1 ± 5.2)	D695	300 (43.5)	300 (43.5)
Compressive Modulus	GPa	D695	4.1 ± 0.3 (591.0 ± 37.0)	D695	59 (8,557)	59 (8,557)
Notched Izod Impact Resistance	J/m	D256	47.9 ± 3.8	D256	810 (15.2)	810 (15.2)
Density	g/cm <sup>3</sup>	-	1.27 ± 0.03	-	1.20	1.20
HDT (1.8 MPa)	deg C (deg F)	D648	150.8 (303.4)	-	190 (374)	190 (374)
HDT (0.45 MPa)	deg C (Deg F)	D648	165.1 (329.2)	-	190 (374)	190 (374)

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<sup>1</sup> The "ULTEM™" and 9085 trademarks are used under license from SABIC, its affiliates or subsidiaries.

<sup>2</sup> CF-HT and CF-HT-A values are derived from pure fiber test specimens. Actual part strength will depend on the amount and pathing of fiber in the part.

<sup>3</sup> CF-HT-A is recommend for material and system qualification.

## Outgassing

Vega exhibits low outgassing, ensuring suitability for critical aerospace applications.

Property	Test (ASTM)	TML (%)	CVCM (%)	WVR (%)
Outgassing	E595-15	0.47	<0.01	0.21

## Chemical Resistance

Property	Vega
37% Hydrochloric Acid	A
80% Phosphoric Acid	A
49% Hydrogen Fluoride	A
50% Potassium Hydroxide	A
50% Hydrogen Peroxide	A
Ethanol	A
Jet A	A
Skydrol	A
Toluene	B
MEK	B
Trichlorethane	C
Dichloromethane	C

### Legend

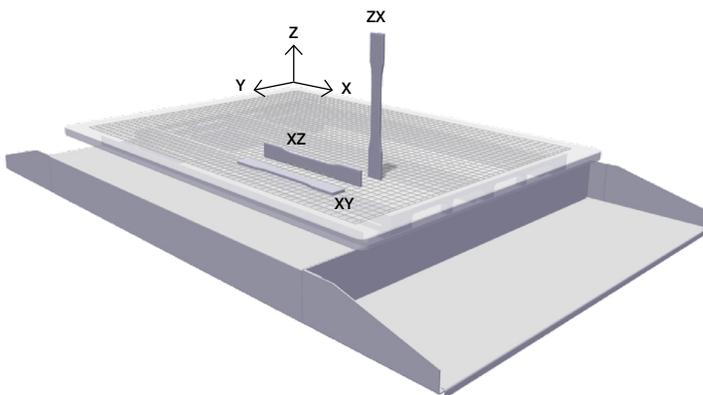
A - Little / no effect

B - Small / moderate effect

C - Significant effect

## Directional Mechanical Properties of Vega

The mechanical properties of 3D printed materials may vary with print orientation. In tension, most parts are strongest when the print orientation and loading direction are parallel, and weakest when the print orientation and loading direction are perpendicular.



Property <sup>4</sup>	Print orientation	Average
Tensile strength (MPa)	XY	65.2 ± 3.0
	XZ	87.6 ± 3.0
	ZX	47.5 ± 3.3
Tensile modulus (GPa)	XY	4.0 ± 0.1
	XZ	5.2 ± 0.2
	ZX	3.3 ± 0.2
Elongation at break (%)	XY	3.9 ± 0.4
	XZ	3.0 ± 0.2
	ZX	5.2 ± 0.5

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<sup>4</sup> XY and XZ specimens were printed with default solid fill settings. ZX specimens were printed with solid fill settings with 6 walls and 4 floors.

## Flame, Smoke, and Toxicity (FST) Performance

Vega alone and with Carbon Fiber reinforcement have demonstrated Flammability test performance that passes CFR 25.853 specifications at 2mm thickness. For information on how this limits potential applications see PS-ANM-25.853-01-R2. Smoke test performance passed CFR 25.853 specifications at 2mm thickness. Combustion toxicity test performance passed Boeing BSS 7239 Flaming specifications at 2mm thickness. Generally thinner specimens have greater difficulty passing testing. Performance of the thinnest specimens that passed testing are shown below.

Test Category	Test Detail	Specification	Thickness	Continuous Fiber Loading	Test	Passing Criteria	Test Result	Outcome	
Flammability	Vertical (60 seg.)	FAR 25.853 Appendix F, Part I (a) (1) (i)	2 mm	None	Burn Time	≤ 15 sec	0 sec	Pass	
					Burn Length	≤ 6 in	3.3 in		
					Longest Burning	≤ 3 sec	None		
				2 mm	Full	Burn Time	≤ 15 sec	0 sec	Pass
					Burn Length	≤ 6 in	3.1 in		
					Longest Burning	≤ 3 sec	None		
	Vertical (12 seg.)	FAR 25.853 Appendix F, Part I (a) (1) (ii)	2 mm	None	Burn Time	≤ 15 sec	2 sec	Pass	
					Burn Length	≤ 8 in	0.9 in		
					Longest Burning	≤ 5 sec	None		
				2.0 mm	Full	Burn Time	≤ 15 sec	0 sec	Pass
				Burn Length	≤ 8 in	0.4 in			
				Longest Burning	≤ 5 sec	None			
Horizontal (15 seg.)	FAR 25.853 Appendix F, Part I (a) (1) (iv)	2.0 mm	None	Avg. Burn Length	≤ 2.5 in/min	0 in/min	Pass		
		2.0 mm	Full	Avg. Burn Length	≤ 2.5 in/min	0 in/min	Pass		
Heat release*	FAR 25.853 Appendix F, Part IV	2.0 mm	None	Avg. Max	≤ 65 kW/m <sup>2</sup>	40.4 kW/m <sup>2</sup>	Pass		
				Avg. 2-min total	≤ 65 kW-min./m <sup>2</sup>	6.9 kW-min./m <sup>2</sup>			
		2.0 mm	Full	Avg. Max	≤ 65 kW/m <sup>2</sup>	34.1 kW/m <sup>2</sup>	Pass		
				Avg. 2-min total	≤ 65 kW-min./m <sup>2</sup>	9.3 kW-min./m <sup>2</sup>			
Smoke	Smoke Density - Flaming Mode	BSS 7238	2.0 mm	None	Ds Max	≤ 200	1	Pass	
	Smoke Density - Non Flaming Mode	BSS 7238	2.0 mm	Full	Ds Max	≤ 200	0	Pass	
Toxicity	Toxicity Flaming	BSS 7239	2.0 mm	None	HCN	≤ 150 PPM	<1 / <1	Pass	
					CO	≤ 3500 PPM	29 / 30		
		NO / NO <sub>2</sub>	≤ 100 PPM	1/1					
		SO <sub>2</sub>	≤ 100 PPM	0 / 0					
		HF	≤ 200 PPM	<1/<1					
		HCL	≤ 500 PPM	<1/<1					
			Full	HCN	≤ 150 PPM	<1/<1	Pass		
				CO	≤ 3500 PPM	39/26			
				NO / NO <sub>2</sub>	≤ 100 PPM	3 / 2			
				SO <sub>2</sub>	≤ 100 PPM	0 / 0			
				HF	≤ 200 PPM	<1 / <1			
				HCL	≤ 500 PPM	<1 / <1			
Toxicity Non Flaming	BSS 7239	2.0 mm		None	HCN	≤ 150 PPM	<1 / <1	Pass	
					CO	≤ 3500 PPM	2 / 3		
				NO / NO <sub>2</sub>	≤ 100 PPM	0 / 1			
				SO <sub>2</sub>	≤ 100 PPM	0 / 0			
				HF	≤ 200 PPM	<1 / <1			
				HCL	≤ 500 PPM	<1 / <1			
				Full	HCN	≤ 150 PPM	<1 / <1	Pass	
				CO	≤ 3500 PPM	<1 / 6			
				NO / NO <sub>2</sub>	≤ 100 PPM	1/1			
				SO <sub>2</sub>	≤ 100 PPM	0 / 0			
				HF	≤ 200 PPM	<1/<1			
				HCL	≤ 500 PPM	<1/<1			

\* Per PS-ANM-25.853-01-R2, the Heat Release test is not required for most interior-facing parts printable on the X7, as they have exposed-surface area below the specified threshold for cabin components.

\*\*Partial sample produced as a 2-layer sandwich panel

Full fiber specimens are produced using the striped fiber configuration with the maximum fiber usage.

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