AFRL-RX-WP-TM-2013-0229

INNOVATIVE APPROACH FOR HIGH STRENGTH, HIGH THERMAL CONDUCTIVE COMPOSITE MATERIALS: Data Base

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NOVEMBER 2013
Final Report

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Table of Contents

List of Tables

1.0 SUMMARY

Hybrid matrix (polymer and thermal conductivity filler) pitch fiber composites were developed. Testing was performed on multiple pitch fiber types, from which we were able to down select K6356U pitch fiber with balanced TC and strength properties. A prepreg processing line was created capable of infusing the unidirectional pitch fiber tape. This processing line has the capability to be used with other fiber types as well. Aluminum hybrid matrix composites were manufactured using a resin exfusion process as well as conventional compression molding, so as to compare the two processes. It was found that compression molding outperforms autoclaving in regards to both thermal and mechanical properties.

Highlights:

- Increasing the thermal and mechanical properties of aluminum particulate pitch fiber composites over control composites
- Creating a robust prepreg processing line to infuse unidirectional pitch fiber tape that can be used with other fibers…Pan-based carbon or glass
- In-plane TC numbers reaching 25-30 W/m*K for quasi-isotropic pitch fiber composites
- Transverse TC numbers more than double that of control pitch fiber composites
- Compression molding process outperforms autoclaving in mechanical and thermal properties using the same prepreg material and process conditions (better particle packing behavior)
- Cost per pound of P^2SI's prepreg material drops by 38%/pound making it a viable alternative to steel or aluminum components. The price to produce P_2SI's hybrid-aluminum-filled pitch fiber prepreg is: $88/pound.

2.0 DATABASE

Table 1: Autoclaved 0° Flexure Strength and Modulus

Material:	K6356U/ 30% Alum. Filled /862W Prepreg Autoclaved								
Matrix Content:	62.91	**% (w/w)**		**Composite Density:**		1.704	**g/cm^3**		
Fiber Volume:	37.10	**%**		**Fiber Areal Weight:**		154.0	**gsm**		
Ply Thickness:	0.0078	**inches**							
Test Method:	ASTM D790: 0°-Flexure Strength and Modulus								
Normalization:	Normalized to 50% Fiber volume								
Test Temperature (°F)		RT		RT		250		250	
Moisture Saturation (%)		0.0		0.212		0.0		0.212	
Environmental Conditioning		Dry		Wet		Dry		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Flexure Strength (σ_{11})	**Mean MPa (ksi)**	662 (96.0)	491 (71.2)	603 (87.4)	447 (64.8)	445 (64.5)	330 (47.9)	337 (48.9)	250 (36.3)
	Minimum	637 (92.4)	473 (68.6)	560 (81.2)	416 (60.3)	423 (61.3)	314 (45.5)	325 (47.0)	241 (34.9)
	Maximum	673 (97.6)	499 (72.4)	657 (95.3)	487 (70.6)	475 (68.9)	353 (51.2)	351 (50.9)	260 (37.7)
	Standard Deviation MPa (ksi)	15 (2.18)	11 (1.60)	40 (5.8)	30 (4.4)	23 (3.3)	17 (2.5)	10 (1.5)	7 (1.0)
	Number Specimens	5	5	5	5	4	4	5	5
Flexure Modulus (E_{11})	**Mean GPa (msi)**	90.6 (13.1)	67.2 (9.7)	92.1 (13.4)	68.4 (9.9)	95.0 (13.8)	70.5 (10.2)	63.2 (9.2)	46.9 (6.8)
	Minimum	88.0 (12.8)	65.3 (9.5)	88.3 (12.8)	65.5 (9.5)	92.0 (13.3)	68.0 (9.9)	55.1 (8.0)	60.4 (8.8)
	Maximum	94.2 (13.7)	69.9 (10.1)	95.2 (13.8)	70.7 (10.3)	98.0 (14.2)	73.0 (10.6)	81.4 (11.8)	40.9 (5.9)
	Standard Deviation GPa (msi)	2.5 (0.4)	1.8 (0.3)	2.6 (0.4)	1.9 (0.3)	3.3 (0.5)	2.4 (0.3)	11.1 (1.6)	8.2 (1.2)
	Number Specimens	5	5	5	5	4	4	5	5
Peak Strain (ε_{11})	**Mean (%)**	NA	1.057	NA	0.903	NA	0.775	NA	1.302
	Minimum		0.972		1.150		0.700		0.995
	Maximum		1.112		0.725		0.880		2.047
	Standard Deviation (%)		0.061		0.157		0.076		0.435
	Number Specimens		5		5		5		5

Table 2: Compression Molded 0° Flexure Strength and Modulus

Material:	K6356U / 30% Alum. Filled / 862W Compression Molded						
Matrix Content:	62.91 (1-3)	**% (w/w)**		**Composite Density:**		1.782 (1) 1.834 (2) 1.839 (3)	**g/cc**
Fiber Volume:	38.50 (1) 34.40 (2) 36.60 (3)	**%**		**Fiber Areal Weight:**		154.00 (1-3)	**gsm**
Ply Thickness:	0.0072 (1) 0.0084 (2) 0.0079 (3)	**inches**					
Test Method:	ASTM D790: 0°-Flexure Strength and Modulus						
Normalization:	Normalized to 50% Fiber volume						

Test Temperature (°F)		CMP-1 RT		CMP-3 RT		CMP-2 250	
Moisture Saturation (%)		0.0		0.212		0.0	
Environmental Conditioning		Dry		Wet		Dry	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Flexure Strength (σ_{11})	**Mean MPa (ksi)**	735 (107)	566 (82)	641 (93)	469 (68)	567 (82)	390 (57)
	Minimum	688 (100)	530 (77)	617 (89)	452 (66)	525 (76)	361 (52)
	Maximum	783 (114)	603 (87)	658 (95)	482 (70)	612 (89)	421 (61)
	Standard Deviation MPa (ksi)	34 (5)	26 (4)	17 (2)	13 (2)	40 (6)	28 (4)
	Number Specimens	5	5	5	5	4	4
Flexure Modulus (E_{11})	**Mean GPa (msi)**	104.4 (15.1)	80.4 (11.7)	98.1 (14.2)	71.8 (10.4)	155.7 (22.6)	107.1 (15.5)
	Minimum	100.4 (14.6)	77.3 (11.2)	94.8 (13.7)	69.4 (10.1)	141.3 (20.5)	116.8 (16.9)
	Maximum	107.7 (15.6)	82.9 (12.0)	100.4 (14.6)	73.5 (10.7)	169.8 (24.6)	97.2 (14.1)
	Standard Deviation GPa (msi)	2.8 (0.4)	2.2 (0.3)	2.2 (0.3)	1.6 (0.2)	13.2 (1.9)	9.1 (1.3)
	Number Specimens	5	5	5	5	4	4
Peak Strain (ε_{11})	**Mean (%)**	NA	0.927	NA	1.111	NA	0.587
	Minimum		0.871		0.910		0.504
	Maximum		0.999		1.295		0.659
	Standard Deviation (%)		0.049		0.137		0.069
	Number Specimens		5		5		4

Table 3: Autoclaved 90° Flexure Strength and Modulus

Material:	K6356U / 30% Alum. Filled / 862W								
Matrix Content:	62.91	**% (w/w)**		**Composite Density:**	1.704		**g/cm^3**		
Fiber Volume:	37.10	**%**		**FAW:**	154.00		**gsm**		
Ply Thickness:	0.0078	**inches**							
Test Method:	ASTM D790: 90°-Flexure Strength and Modulus								
Normalization:	NA								
Test Temperature (°F)		RT		RT		250		250	
Moisture Saturation (%)		0.0		0.283		0.0		0.283	
Environmental Conditioning		Dry		Wet		Dry		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Flexure Strength σ_{11}	**Mean MPa (ksi)**	NA	30.4 (4.4)	NA	37.8 (5.5)	NA	36.1 (5.2)	NA	23.6 (3.4)
	Minimum	NA	28.4 (4.1)	NA	33.2 (4.8)	NA	25.2 (3.7)	NA	21.2 (3.1)
	Maximum	NA	36.4 (5.3)	NA	43.9 (6.4)	NA	45.2 (6.6)	NA	25.9 (3.8)
	Standard Deviation MPa (ksi)	NA	3.4 (0.5)	NA	5.0 (0.7)	NA	7.7 (1.1)	NA	2.2 (0.3)
	Number Specimens	NA	5	NA	5	NA	5	NA	5
Flexure Modulus E_{11}	**Mean GPa (msi)**	NA	4.68 (0.68)	NA	4.98 (0.72)	NA	Noisy	NA	Noisy
	Minimum	NA	4.53 (0.66)	NA	4.83 (0.70)	NA		NA	
	Maximum	NA	4.88 (0.71)	NA	5.20 (0.75)	NA		NA	
	Standard Deviation (GPA)	NA	0.13 (0.02)	NA	0.15 (0.02)	NA		NA	
	Number Specimens	5	5	NA	5	NA		NA	
Peak Strain ε_{11}	**Mean**	NA	0.657	NA	0.841	NA	0.964	NA	Noisy
	Minimum	NA	0.603	NA	0.703	NA	0.710	NA	
	Maximum	NA	0.811	NA	0.992	NA	1.230	NA	
	Standard Deviation (%)	NA	0.087	NA	0.118	NA	0.224	NA	
	Number Specimens	NA	5	NA	5	NA	5	NA	

Table 4: Compression Molded 90° Flexure Strength and Modulus

Material:	K6356U / 30% Alum. Filled / 862W Compression Molded						
Matrix Content:	62.91 (1-3)	**% (w/w)**		**Composite Density:**		1.782 (1) 1.834 (2) 1.839 (3)	**g/cc**
Fiber Volume:	38.50 (1) 34.40 (2) 36.60 (3)	**%**		**Fiber Areal Weight:**		154.00 (1-3)	**gsm**
Ply Thickness:	0.0072 (1) 0.0084 (2) 0.0079 (3)	**inches**					
Test Method:	ASTM D790: 90°-Flexure Strength and Modulus						
Normalization:	NA						

Test Temperature (°F)		CMP-1 RT		CMP-3 RT		CMP-2 250	
Moisture Saturation (%)		0.0		0.212		0.0	
Environmental Conditioning		Dry		Wet		Dry	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Flexure Strength (σ_{11})	**Mean MPa (ksi)**	NA	33.07 (4.80)	NA	38.90 (5.64)	NA	25.37 (3.68)
	Minimum		30.27 (4.39)		36.63 (5.31)		23.98 (3.48)
	Maximum		37.45 (5.43)		40.69 (5.90)		26.66 (3.87)
	Standard Deviation MPa (ksi)		3.22 (0.47)		1.51 (0.22)		1.35 (0.20)
	Number Specimens		5		5		3
Flexure Modulus (E_{11})	**Mean MPa (ksi)**		3936.9 (570.9)		4754.5 (689.4)		3294.8 (477.7)
	Minimum		3801.2 (551.2)		4687.1 (679.6)		3080.5 (446.7)
	Maximum		4037.4 (585.4)		4830.3 (700.4)		3561.6 (516.4)
	Standard Deviation MPa (ksi)		87.5 (12.7)		53.9 (7.8)		244.8 (35.5)
	Number Specimens		5		5		3
Peak Strain (ε_{11})	**Mean (%)**		0.892		0.898		0.801
	Minimum		0.787		0.853		0.740
	Maximum		1.011		0.925		0.898
	Standard Deviation (%)		0.091		0.028		0.085
	Number Specimens		5		5		3

Table 5: Autoclaved Short Beam Shear Strength

Material:	K6356U / 30% Alum. Filled / 862W					
Matrix Content:	62.91	**% (w/w)**	**Composite Density:**	1.7690	**g/cm^3**	
Fiber Volume:	37.10	**%**	**Fiber Areal Weight:**	154.0	**gsm**	
Ply Thickness:	0.0078	**inches**				
Test Method:	ASTM D2344: Short Beam Shear Strength $[0]_{16}$					
Normalization:	NA					

Test Temperature (°F)		RT	RT	250	250
Moisture Saturation (%)		0.0	0.309	0	0.309
Environmental Conditioning		Dry	Wet	Dry	Wet
Mechanical Property		**Measured**	**Measured**	**Measured**	**Measured**
SHORT BEAM SHEAR STRENGTH (S_H)	**Mean MPa (ksi)**	42.4 (6.1)	39.4 (5.7)	20.2 (2.9)	20.0 (2.9)
	Minimum	40.5 (5.9)	36.3 (5.3)	19.2 (2.8)	17.5 (2.5)
	Maximum	44.1 (6.4)	41.0 (5.9)	20.5 (3.0)	22.3 (3.2)
	Standard Deviation MPa (ksi)	1.3 (0.2)	2.0 (0.3)	0.6 (.09)	1.9 (0.28)
	Number Specimens	5	5	5	5

Table 6: Compression Molded Short Beam Shear Strength

Material:	K6356U / 30% Alum. Filled / 862W Compression Molded						
Matrix Content:	62.91 (1-3)	**% (w/w)**		**Composite Density:**		1.782 (1) 1.834 (2) 1.839 (3)	**g/cc**
Fiber Volume:	38.50 (1) 34.40 (2) 36.60 (3)	**%**		**Fiber Areal Weight:**		154.0 (1-3)	**gsm**
Ply Thickness:	0.0072 (1) 0.0084 (2) 0.0079 (3)	**inches**					
Test Method:	ASTM D2234: Short Beam Shear Properties						
Normalization:	NA						

ID and Test Temperature (°F)		CMP-1 RT		CMP-3 RT		CMP-2 250	
Moisture Saturation (%)		0.0		0.212		0.0	
Environmental Conditioning		Dry		Wet		Dry	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
SBS Shear Strength (S_{h})	**Mean MPa (ksi)**	NA	47.07 (6.83)	NA	45.77 (6.64)	NA	20.05 (2.91)
	Minimum		45.34 (6.57)		44.35 (6.43)		18.66 (2.71)
	Maximum		48.41 (7.02)		47.86 (6.94)		21.25 (3.08)
	Standard Deviation MPa (ksi)		1.17 (0.17)		1.63 (0.24)		0.99 (0.14)
	Number Specimens		5		5		5

Table 7: Autoclaved Compression Strength

Material:	K6356U / 30% Alum. Filled / 862W								
Matrix Content:	62.91	**% (w/w)**		**Composite Density:**	1.769	**g/cm^3**		
Fiber Volume:	37.10	**%**		**Fiber Areal Weight:**	154.0	**gsm**		
Ply Thickness:	0.0078	**inches**						
Test Method:	ASTM D695 Compression Strength $[0]_{16}$							
Normalization:	Normalize to 50% Fiber volume							
Test Temperature (°F)		RT		RT		250		250	
Moisture Saturation (%)		0.0		0.321		0.0		0.321	
Environmental Conditioning		Dry		Wet		Dry		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Compression Strength σ_{11}	**Mean MPa (ksi)**	331 (48.0)	246 (35.7)	311 (45.1)	231 (33.5)	299 (43.4)	222 (32.2)	157 (22.8)	117 (17.0)
	Minimum	315 (45.7)	234 (33.9)	303 (43.9)	225 (32.6)	285	211 (30.6)	135 (19.6)	100 (14.5)
	Maximum	366 (53.1)	272 (39.4)	321 (46.5)	238 (34.5)	314 (45.5)	233 (33.8)	195 (28.3)	120 (17.4)
	Standard Deviation MPa (ksi)	20 (2.9)	15 (2.2)	8 (1.2)	6 (0.87)	11 (1.6)	8 (1.2)	23 (3.3)	17 (2.5)
	Number Specimens	5	5	5	5	5	5	5	5

Table 8: Compression Molded Compression Strength

Material:	K6356U / 30% Alum. Filled / 862W Compression Molded						
Matrix Content:	62.91 (1-3)	**% (w/w)**		**Composite Density:**		1.782 (1) 1.834 (2) 1.839 (3)	**g/cc**
Fiber Volume:	38.50 (1) 34.40 (2) 36.60 (3)	**%**		**Fiber Areal Weight:**		154.0 (1-3)	**gsm**
Ply Thickness:	0.0072 (1) 0.0084 (2) 0.0079 (3)	**inches**					
Test Method:	ASTM D695: Compression Strength Properties $[0]_{16}$						
Normalization:	NA						

Test Temperature (°F)		CMP-1 RT		CMP-3 RT		CMP-2 250	
Moisture Saturation (%)		0.0		0.212		0.0	
Environmental Conditioning		Dry		Wet		Dry	
		Normalized	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Compression Strength (σ_{11})	**Mean MPa (ksi)**	373.58 (54.17)	287.66 (41.71)	317.36 (46.02)	232.31 (33.68)	275.42 (39.94)	189.49 (27.48)
	Minimum	351.39 (50.95)	270.57 (39.23)	284.69 (41.28)	208.39 (30.22)	272.65 (39.53)	187.58 (27.20)
	Maximum	402.40 (58.35)	309.85 (44.93)	336.53 (48.80)	246.34 (35.72)	278.20 (40.34)	191.40 (27.75)
	Standard Deviation MPa (ksi)	20.22 (2.93)	15.57 (2.26)	19.92 (2.89)	14.58 (2.11)	3.93 (0.57)	2.70 (0.39)
	Number Specimens	5	5	5	5	2	2

Table 9: Autoclaved 0° Tensile Strength and Modulus

Material:	K6356U / 30% Alum. Filled / 862W								
Matrix Content:	62.91	**% (w/w)**		**Composite Density:**		1.845	**g/cm^3**		
Fiber Volume:	34.50	**%**		**Fiber Areal Weight:**		154.0	**gsm**		
Ply Thickness:	0.0084	**inches**							
Test Method:	ASTM D3039: 0-Tension and Modulus $[0]_5$								
Normalization:	Normalize to 50% fiber volume								
Test Temperature (°F)		RT ONLY		RT		250		250	
Moisture Saturation (%)		NA		0		0		0	
Environmental Conditioning		Dry		Wet		Dry		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Ultimate Tensile Strength (σ_{11})	**Mean MPa (ksi)**	1645.6 (238.6)	1135.5 (164.6)						
	Minimum	1549.1 (224.6)	1068.9 (155.0)						
	Maximum	1750.1 (253.8)	1207.6 (175.1)						
	Standard Deviation MPa (ksi)	89.8 (13.0)	61.9 (9.0)						
	Number Specimens	6	6						
Tensile Modulus (E_{11})	**Mean GPa (msi)**	304.9 (44.2)	210.4 (30.5)						
	Minimum	286.5 (41.5)	197.7 (28.7)						
	Maximum	322.6 (46.8)	222.6 (32.3)						
	Standard Deviation GPa (msi)	14.2 (2.1)	9.8 (1.4)						
	Number Specimens	6	6						
Poisson's Ratio (ν_{12})	**Mean**	NA	0.3562						
	Minimum		0.3150						
	Maximum		0.3920						
	Standard Deviation		0.0282						
	Number Specimens		6						
Peak Strain (ε_{11})	**Mean (%)**	NA	0.53						
	Minimum		0.51						
	Maximum		0.56						
	Standard Deviation (%)		0.0002						
	Number Specimens		6						

Table 10: Autoclaved 90° Tensile Strength and Modulus

Material:	K6356U / 30% Alum. Filled / 862W					
Matrix Content:	62.91	**% (w/w)**		**Density:**	1.7630	**g/cm^3**
Fiber Volume:	37.70	**%**		**FAW:**	154.0	**gsm**
Ply Thickness:	0.0077	**inches**				
Test Method:	ASTM D3039: 90°Tension Strength and Modulus $[0]_{10}$					
Normalization:	NA					

Test Temperature (°F)		RT		RT		250		250	
Moisture Saturation (%)		0.0		0.266		0.0		0.266	
Environmental Conditioning		None		Wet		None		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Tensile Strength (σ_{11})	**Mean (MPa)**	NA	19.89 (2.88)	NA	17.92 (2.60)	NA	11.15 (1.62)	NA	9.17 (1.33)
	Minimum		19.88 (2.88)		NA		8.98 (1.30)		8.20 (1.19)
	Maximum		19.90 (2.89)		NA		14.35 (2.08)		10.31 (1.49)
	Standard Deviation (MPa)		0.02 (0.003)		0.0		2.83 (0.41)		1.06 (0.15)
	Number Specimens		2		1		3		3
Tensile Modulus (E_{11})	**Mean (GPa)**	NA	6.81 (0.99)	NA	7.21 (1.05)	NA	4.38 (0.64)	NA	3.43 (0.50)
	Minimum		6.80 (0.99)		NA		4.01 (0.58)		3.68 (0.53)
	Maximum		6.82 (0.99)		NA		5.01 (0.73)		3.21 (0.47)
	Standard Deviation (GPa)		0.01 (0.002)		0.0		0.55 (0.08)		0.23 (0.03)
	Number Specimens		2		1		3		3
Poisson's Ratio (ν_{12})	**Mean**	NA	0.021	NA	0.015	NA	0.027	NA	0.0052
	Minimum		0.017		NA		0.021		0.0054
	Maximum		0.024		NA		0.038		0.0051
	Standard Deviation		0.005		0.00		0.009		0.0002
	Number Specimens		2		1		3		3
Peak Strain (ε_{11})	**Mean (%)**	NA	0.280	NA	0.253	NA	(Noisy)	NA	0.409
	Minimum		0.229		NA				0.386
	Maximum		0.330		NA				0.441
	Standard Deviation (%)		0.071		0.00				0.028
	Number Specimens		2		1				3

Table 11: Autoclaved Northrop Grumman Open-Hole Compression Strength

Material:	K6356U / 30% Alum. Filled / 862W Prepreg Autoclaved								
Resin Content:	65.92	**% (w/w)**		**Composite Density:**		1.7780	**g/cm^3**		
Fiber Volume:	35.10	**%**		**FAW:**		154.0	**gsm**		
Ply Thickness:	0.0081	**inches**							
Test Method:	Northrop Grumman: Open-Hole Compression $[45, 0, -45, 90]_{3s}$								
Normalization:	Normalize to 50% fiber volume								
Test Temperature (°F)		75		75		250		250	
Moisture Saturation (%)		0.0		0.120		0.0		0.120	
Environmental Conditioning		None		Wet		None		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Open Hole Compression Strength σ_{11}	**Mean MPa (ksi)**	145 (21)	102 (15)	141 (20)	99 (14)	108 (16)	76 (11)	104 (15)	73 (11)
	Minimum	140 (20)	98 (14)	130 (19)	91 (13)	93 (13)	65 (9)	100 (15)	75 (11)
	Maximum	151 (22)	106 (15)	148 (21)	104 (15)	117 (17)	82 (12)	107 (16)	71 (10)
	Standard Deviation MPa (ksi)	5 (0.7)	4 (0.6)	7 (1.0)	5 (0.7)	9 (1.3)	6 (0.9)	3 (0.4)	2 (0.3)
	Number Specimens	5	5	5	5	5	5	5	5

Table 12: Autoclaved In-Plane Shear Strength and Modulus

Material:	K6356U / 30% Alum. Filled / 862W Prepreg, Autoclaved								
Matrix Content:	62.91	**% (w/w)**		**Composite Density:**		1.716	**g/cm^3**		
Fiber Volume:	32.60	**%**		**Fiber Areal Weight:**		147.0	**gsm**		
Ply Thickness:	0.0085	**inches**							
Test Method:	ASTM D3518: In-Plane Shear Strength and Modulus $[45, -45, -45, 45]_{2s}$								
Normalization:	NA								
Test Temperature (°F)		RT		RT		250		250	
Moisture Saturation (%)		NA		0.429		NA		0.429	
Environmental Conditioning		Dry		Wet		Dry		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Maximum Shear Stress (τ_{12})	**Mean MPa (ksi)**	NA	35.69 (5.18)	NA	35.14 (5.10)	NA	19.67 (2.85)	NA	20.35 (2.95)
	Minimum		31.04 (4.50)		32.44 (4.70)		16.24 (2.35)		19.18 (2.78)
	Maximum		40.78 (5.91)		37.90 (5.50)		23.88 (3.46)		21.05 (3.05)
	Standard Deviation MPa (ksi)		4.46 (0.65)		1.99 (0.29)		3.11 (0.45)		0.73 (0.11)
	Number Specimens		5		4		5		5
Chord Shear Modulus (G_{12})	**Mean MPa (ksi)**		3201.7 (464.2)		3090.8 (448.2)		1827.8 (265.0)		1584.1 (229.7)
	Minimum		NA		2904.5 (421.2)		1623.8 (235.5)		1413.7 (205.0)
	Maximum		NA		3230.8 (468.5)		1939.2 (281.2)		1706.0 (247.4)
	Standard Deviation MPa (ksi)		0.0		145.7 (21.1)		126.3 (18.3)		118.1 (17.1)
	Number Specimens		1		4		5		5
Shear Stress at 5% Shear Strain (τ_{12}) (if applicable)	**Mean**		NA		NA		13.64 (1.98)		16.17 (2.34)
	Minimum						11.71 (1.70)		14.69 (2.13)
	Maximum						17.54 (2.54)		17.46 (2.53)
	Standard Deviation						2.35 (0.34)		1.17 (0.17)
	Number Specimens						5		5

Table 13: Autoclaved Compression after Impact Strength

Material:	K6356U / 30% Alum. Filled / 862W Prepreg, Autoclaved								
Matrix Content:	65.92	**% (w/w)**		**Composite Density:**		1.775	**g/cm^3**		
Fiber Volume:	35.50	**%**		**Fiber Areal Weight:**		147.0	**%**		
Ply Thickness:	0.0078	**inches**							
Test Method:	ASTM D7137 Compression after Impact Strength $[45, 0, -45, 90]_{3s}$								
Normalization:	Normalize to 50% Fiber volume								

Test Temperature (°F)		DRY-CONTROL-RT		WET-CONTROL-RT		Impacted-DRY-RT		Impacted-WET-RT	
Moisture Saturation (%)		0.0		0.202		0.0		0.202	
Environmental Conditioning		Dry		Wet		Dry		Wet	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Compression after Impact Strength (σ_{11})	**Mean MPa (ksi)**	148.57 (21.54)	105.48 (15.29)	159.21 (23.09)	113.04 (16.39)	135.34 (19.62)	96.09 (13.93)	128.33 18.61)	91.11 (13.21)
	Minimum	NA	NA	NA	NA	NA	NA	NA	NA
	Maximum	NA	NA	NA	NA	NA	NA	NA	NA
	Standard Deviation MPa (ksi)	NA	NA	NA	NA	NA	NA	NA	NA
	Number Specimens	1	1	1	1	1	1	1	1

Table 14: Autoclaved Transverse and In-Plane Thermal Conductivity

Material:	K6356U / 30% Alum. Filled / 862W Prepreg, Autoclaved								
Resin Content:	65.92	**% (w/w)**		**Composite Density:**		1.7780	**g/cm^3**		
Fiber Volume:	35.10	**%**		**Fiber Areal Weight:**		154.0	**gsm**		
Ply Thickness:	0.0081	**inches**							
Test Method:	P2SI's Transverse (TT) and In-Plane (IP) Thermal Conductivity Properties [45, 0, -45, 90]$_{3s}$								
Normalization:	Normalize to 50% fiber volume								
Test Temperature (°F)		RT-DRY-TT		RT-WET-TT		RT-DRY-IP		RT-WET-IP	
Moisture Saturation (%)		0.0		0.364		0.0		0.364	
Environmental Conditioning		None		Wet		None		Wet	
Thermal Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Thermal Conductivity (W/m*K)	**Mean (W/m*K)**	1.603	1.125	1.815	1.274	28.623	20.093	25.218	17.703
	Minimum	1.503	1.055	NA	NA	26.093	18.317	21.705	15.237
	Maximum	1.702	1.195	NA	NA	31.151	21.868	28.732	20.170
	Standard Deviation (W/m*K)	0.141	0.099	NA	NA	3.577	2.511	4.969	3.488
	Number Specimens	2	2	1	1	2	2	2	2

Table 15: Compression Molded Transverse RT-DRY Thermal Conductivity

Material:	K6356U / 30% Alum. Filled / 862W Prepreg, Compression Molded						
Matrix Content:	62.91 (1-3)	**% (w/w)**		**Composite Density:**		1.782 (1) 1.834 (2) 1.839 (3)	**g/cc**
Fiber Volume:	38.50 (1) 34.40 (2) 36.60 (3)	**%**		**Fiber Areal Weight:**		154.00 (1-3)	**gsm**
Ply Thickness:	0.0072 (1) 0.0084 (2) 0.0079 (3)	**inches**					
Test Method:	P2SI Transverse Thermal Conductivity Properties-RT-DRY $[0]_{16}$						
Normalization:	NA						

Test Temperature (°F)		CMP-1 (RT)		CMP-2 (RT)		CMP-3 (RT)	
Moisture Saturation (%)		0.0		0.0		0.0	
Environmental Conditioning		Dry		Dry		Dry	
Thermal Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Transverse Thermal Conductivity (W/m*K)	**Mean (W/m*K)**	2.839	2.186	3.602	2.478	3.081	2.255
	Minimum	2.816	2.168	NA	NA	NA	NA
	Maximum	2.861	2.203	NA	NA	NA	NA
	Standard Deviation (W/m*K)	0.032	0.025	NA	NA	NA	NA
	Number Specimens	2	2	1	1	1	1

Table 16: Compression Molded RT-WET Transverse Thermal Conductivity

Material:	K6356U / 30% Alum. Filled / 862W Prepreg, Compression Molded					
Matrix Content:	62.91 (1-3)	**% (w/w)**		**Composite Density:**	1.782 (1) 1.834 (2) 1.839 (3)	**g/cc**
Fiber Volume:	38.50 (1) 34.40 (2) 36.60 (3)	**%**		**Fiber Areal Weight:**	154.0 (1-3)	**gsm**
Ply Thickness:	0.0072 (1) 0.0084 (2) 0.0079 (3)	**inches**				
Test Method:	P2SI Transverse Thermal Conductivity Properties-RT-WET $[0]_{16}$					
Normalization:	NA					

Test Temperature (°F)		CMP-1 (RT)		CMP-2 (RT)		CMP-3 (RT)	
Moisture Saturation (%)		0.363		0.363		0.363	
Environmental Conditioning		WET		WET		WET	
Thermal Property		**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
Transverse Thermal Conductivity (W/m*K)	**Mean (W/m*K)**	2.782	2.142	3.331	2.292	2.977	2.179
	Minimum	2.778	2.139	3.167	2.179	NA	NA
	Maximum	2.786	2.145	3.497	2.406	NA	NA
	Standard Deviation (W/m*K)	0.006	0.005	0.233	0.160		
	Number Specimens	2	2	2	2	1	1

Table 17: Autoclaved Fracture Toughness by Mix-Mode Bending

Material:	K6356U / 30% Alum. Filled / 862W Prepreg, Autoclaved					
Matrix Content:	62.90	**% (w/w)**		**Composite Density:**	1.699	**g/cc**
Fiber Volume:	33.90	**%**		**Fiber Areal Weight:**	147.0	**gsm**
Ply Thickness:	0.0082	**inches**				
Test Method:	ASTM D-6671 Mixed Mode I-Mode II Interlaminar Fracture Toughness of Unidirectional Fiber Reinforced Polymer Matrix Composites [0_{16}]					
Normalization:	NA					

Test Temperature (°F)		RT		RT	
Moisture Saturation (%)		0.0		0.440	
Environmental Conditioning		DRY		WET	
Mechanical Property		**Normalized**	**Measured**	**Normalized**	**Measured**
Mode I Fracture Toughness (G_I)	**Mean (J/m^2)**	NA	202.95	NA	158.53
	Minimum		101.51		98.50
	Maximum		349.23		233.18
	Standard Deviation (J/m2)		108.02		55.87
	Number Specimens		4		5
Mode I Fracture Toughness (G_I)	**Mean (J/m^2)**	NA	52.49	NA	35.92
	Minimum		26.82		22.12
	Maximum		93.99		53.21
	Standard Deviation (J/m2)		29.11		12.97
	Number Specimens		4		5
Percent Mode II Fracture Toughness (% G_{II})	**Mean (%)**	NA	20.52	NA	18.41
	Minimum		18.49		22.12
	Maximum		21.53		53.21
	Standard Deviation (%)		1.38		0.12
	Number Specimens		4		5

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AFRL-RX-WP-TM-2013-0229 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
November 2013	Final	7 April 2011- 15 October 2013

4. TITLE AND SUBTITLE
INNOVATIVE APPROACH FOR HIGH STRENGTH, HIGH THERMAL CONDUCTIVE COMPOSITE MATERIALS: Data Base

5a. CONTRACT NUMBER
FA8650-11-C-5103

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
65502F

6. AUTHOR(S)
Robert J. Jurek and David B. Curliss

5d. PROJECT NUMBER
3005

5e. TASK NUMBER

5f. WORK UNIT NUMBER
X0TQ

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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Moraine, OH 45409-1501

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory
Materials and Manufacturing Directorate
Wright-Patterson Air Force Base, OH 45433-7750
Air Force Materiel Command
United States Air Force

10. SPONSORING/MONITORING AGENCY ACRONYM(S)
AFRL/RXCC

11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)
AFRL-RX-WP-TM-2013-0229

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
PA Case Number: 88ABW-2013-5423; Clearance Date: 20 Dec 2013. Report contains color. For additional information see AFRL-RX-WP-TR-2013-0216.

14. ABSTRACT ***(Maximum 200 words)***

Using the format of Mil Handbook 17, a complete data base of the results of experimental efforts to determine hybrid matrix pitch fiber composites. Testing was performed on multiple pitch fiber types, from which we were able to down select K6356U pitch fiber with balanced TC and strength properties. A prepreg processing line was created capable of infusing the unidirectional pitch fiber tape. This processing line has the capability to be used with other fiber types as well. Aluminum-filled composites were manufactured suing a resin exfusion process as well as conventional compression molding. It was found that compression molding outperforms autoclaving in both thermal and mechanical properties.

15. SUBJECT TERMS
data base report, composite materials, pitch carbon fiber, thermal conductivity, highly graphite fibers, composites

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT:	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Monitor)
a. REPORT	b. ABSTRACT	c. THIS PAGE			Roger Gerzeski
Unclassified	Unclassified	Unclassified	SAR	22	19b. TELEPHONE NUMBER *(Include Area Code)* (937) 904-4323