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Mechanical Characterization of 3D Woven Carbon Composite

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September 2017

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This report presents the results of testing performed by Intertek on six 3D woven carbon fiber composites. The panels were woven by 3Tex and Textile Engineering and Manufacturing (TEAM). Vacuum Assisted Resin Transfer Molding (VARTM) was performed by the University of Delaware's Center for Composite Materials. Tensile tests were conducted along all three axis, and shear tests were performed on the x and y axis. The Ultimate Tensile Strength (UTS), Young's Modulus, Shear Modulus, and Poisson's Ratio were calculated for each panel. Each panel showed varying degrees of anisotropy, which is typical for composites. This was particularly notable along the z-axis. The quantitative results for the majority of the tests are suspect and should not be considered accurate. This is due to grip slippage and adhesive failure that occurred during the tensile tests. As a result, further characterization of these materials will be necessary.

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Abstract

This report presents the results of testing performed by Intertek on six 3D woven carbon fiber composites. The panels were woven by 3Tex and Textile Engineering and Manufacturing (TEAM). Vacuum Assisted Resin Transfer Molding (VARTM) was performed by the University of Delaware's Center for Composite Materials. Tensile tests were conducted along all three axis, and shear tests were performed on the x and y axis. The Ultimate Tensile Strength (UTS), Young's Modulus, Shear Modulus, and Poisson's Ratio were calculated for each panel. Each panel showed varying degrees of anisotropy, which is typical for composites. This was particularly notable along the z-axis. The quantitative results for the majority of the tests are suspect and should not be considered accurate. This is due to grip slippage and adhesive failure that occurred during the tensile tests. As a result, further characterization of these materials will be necessary.

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Introduction

3D woven composites, like their more traditional counterparts, consist of reinforcing fibers in a supporting matrix. The defining characteristic of a 3D woven composite is that it includes fibers along the x, y, and z axis. Traditional composites weave fibers only along a single plane. To manufacture parts, these individual weaves or lamina are stacked to achieve the desired properties, and then infused with resin. The through thickness properties are thus comparable to those of the unreinforced matrix. As a result, 2D composites are prone to delamination if subjected to out of plane stresses and are labor intensive to produce. The addition of the z-axis fiber in 3D woven composites addresses these issues. This boosts the inter-laminar strength, and allows for the weaving of near net shape parts. The weaves used in 3D composites differ from those used in 2D composites. The warp (lengthwise/y-axis) and fill (transverse/x-axis) fibers are not typically interlaced; this is left to the z-axis fibers. As a result, in plane properties can actually surpass those of 2D woven composites, and fiber crimp is minimized. This type of weave is also more porous, allowing for quicker resin infiltration (1).

Panels

The panels were woven by two companies. 3Tex wove panels one, five, and six. TEAM wove panels four, seven, and eight (Fig 1). 3Tex opted to use Toho Tenax HTS and HTA fibers, while TEAM used T700s fibers. The woven panel preforms underwent vacuum assisted resin transfer molding (VARTM) by the University of Delaware's Center for Composite Materials. Endurance 4505A resin and 4506B hardener were used as the matrix for each panel. Fiber and matrix properties are given in Table 1. Information on the structure and composition of each panel is given in tables 2-7.

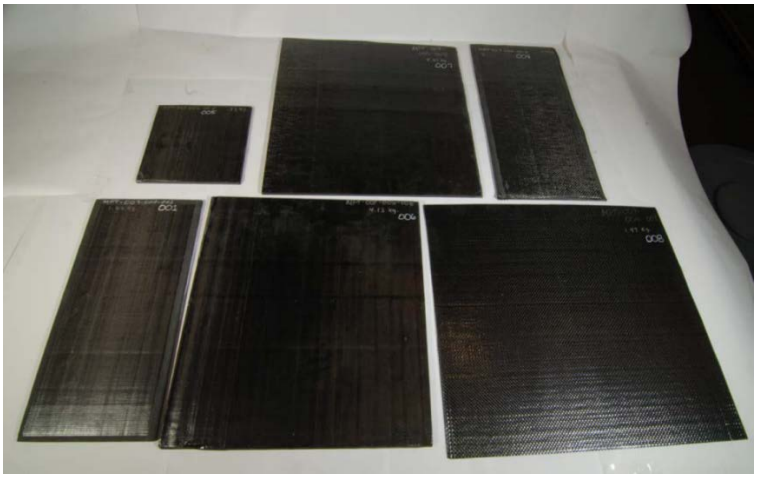


Figure 1: 3D woven carbon composite panels produced by 3Tex and Team.

	Toho Tenax HTA 40 1k	Toho Tenax HTS 40 6&12k	T700S 6&12k	Endurance 4505A w 4506B
Tensile Strength (KSI)	595	638	711	8.5
Young's Modulus (MSI)	34.9	34.9	33.4	.4

Table 1: Mechanical properties of the fibers and resin (2) (3)(4)

MPT-007-006-001

3Tex	Architecture	Layers	Fiber	V_f Volume Fraction	Panel Thickness (as woven)
Warp	Orthogonal	6	Toho Tenax HTS 40 12k	.25	.38
Fill		7	HTS 40 6k outer HTS 40 12k inner	.25	
Z-axis			HTA 40 1k	.02	

Table 2: Panel 001's structure and composition

MPT-007-006-004

TEAM	Architecture	Fiber	V_f	Panel Thickness (as woven)
Warp	Orthogonal	T700S 12k	.23	.45
Fill			.23	
Z-axis		T700S 6k	.02	

Table 3: Panel 004's structure and composition

MPT-007-006-005

3Tex	Architecture	Layers	Fiber	V_f	Panel Thickness (as woven)
Warp	Orthogonal	6	Toho Tenax HTS 40 12k	.25	.38
Fill		7	HTS 40 6k for outer HTS 40 12k for inner	.25	
Z-axis			HTA 40 1k	.02	

Table 4: Panel 005's structure and composition

MPT-007-006-006

3Tex	Architecture	Layers	Fiber	V_f	Panel Thickness (as woven)
Warp	Orthogonal	8	Toho Tenax HTS 40 12k	.25	.5
Fill		9	HTS 40 6k for outer HTS 40 12k for inner	.25	
Z-axis			HTA 40 1k	.02	

Table 5: Panel 006's structure and composition

MPT-007-006-007

TEAM	Architecture	Fiber	V_f	Panel Thickness (as woven)
Warp	Orthogonal	T700S 12k	.23	.45
Fill			.23	
Z-axis		T700S 6k	.02	

Table 6: Panel 007's structure and composition

MPT-007-006-008

TEAM	Architecture	Fiber	V_f	Panel Thickness (as woven)
Warp	Orthogonal	T700S 12k	.16	.14
Fill			.24	
Z-axis		T700S 6k	.07	

Table 7: Panel 008's structure and composition

Testing

Tensile and shear tests were performed by Intertek in accordance with American Society for Testing and Materials (ASTM) standards. Tensile tests were performed according to ASTM D3039M-14 for the in-plane x(90^o) and y axis(0^o), and ASTM D7291M-15 for the through-thickness z axis. The tests were done using an Instron 5985 with hydraulic wedge abrasive grips for the x and y axis, and were bonded to the loading fixtures with Cybercryl 800 for the z axis. Shear tests were done in accordance with ASTM D7078M-12. The Instron 5985 was used for the shear tests as well.

Results

The tensile strength, elastic modulus, shear modulus, and Poisson's ratio for each panel are given in tables 8-13. Figure 2 A-D compares the properties of each panel. The stress strain curves for each test can be found in the appendix.

During all tensile tests, except four, grip slippage occurred. As a result, they were unable to be tested to failure. For these samples, the highest stress achieved was used as an approximation of the tensile strength. The failure mode of every through thickness tensile test involved partial adhesive failure, therefor z-axis tensile strengths are likely inaccurate.

The only panel to not suffer significant slippage during the x and y tests was the 008 panel. This is likely due to it being thinner and thus requiring lower applied loads. 008's Tensile strength is also notably higher in the x and y axis, even though it has the lowest volume fraction of x axis fibers. This may indicate that the strengths of the other panels are actually higher than those reported. 008's z-axis tensile strength is not significantly higher than the other panels. This is despite the fact it has the highest volume fraction of z axis fibers. This indicates that the z axis strengths reported might represent the adhesive used for the test, not the 3d woven composite.

3Tex Panel 001	Tensile Strength (TS) 0°* (KSI/MPa)	TS 90°*	TS Through Thickness (TT) **	Young's Modulus (*E*) 0° (MSI/GPa)	*E* 90°	*E* TT	Shear Modulus (*G*) 0° (KSI/MPa)	*G* 90°	Poisson's Ratio (*v*) 0° (%)	*v* 90°
1	59.8 / 412	66.1 / 456	2.57 / 17.7	10.0 / 68.9	10.9 / 75.2	1.84 / 12.7	397 / 2737	395 / 2723	0.058	0.0507
2	69.4 / 478	63.7 / 439	2.66 / 18.3	9.84 / 67.8	10.6 / 73.1	2.04 / 14.1	395 / 2723	410 / 2827	0.0426	0.0442
3	81.9 / 565	62.2 / 429	2.80 / 19.3	10.70 / 73.8	11.2 / 77.2	2.00 / 13.8	389 / 2682	398 / 2744	0.0349	0.0459
4			2.72 / 18.8			2.00 / 13.8	389 / 2682	400 / 2758		
5			2.88 / 19.9			2.00 / 13.8	400 / 2758	407 / 2806		
Average	**70.4 / 485**	**64.0 / 441**	**2.73 / 18.8**	**10.2 / 70.3**	**10.9 / 75.2**	**1.98 / 13.7**	**394 / 2717**	**402 / 2772**	**0.0452**	**0.0469**
Std. Dev.	11.1 / 77	2.0 / 14	.12 / .8	.46 / 3.2	.30 / 2.1	.08 / .54	4.9 / 34	6.28 / 43.3	0.0118	0.0034
C.O.V. (%)	16	3	4	4	3	4	1	2	26	7

Table 8: Mechanical properties for panel 001.
*grip/**partial adhesive failure occurred

Team Panel 004	Tensile Strength (TS) 0°* (KSI/MPa)	TS 90°*	TS Through Thickness (TT) **	Young's Modulus (*E*) 0° (MSI/GPa)	*E* 90°	*E* TT	Shear Modulus (*G*) 0° (KSI/MPa)	*G* 90°	Poisson's Ratio (*v*) 0° (%)	*v* 90°
1	69.7 / 481	48.3 / 333	2.95 / 20.3	8.22 / 56.7	7.46 / 51.4	1.79 / 12.3	436 / 3006	431 / 2972	0.0476	0.0874
2	69.3 / 478	56.4 / 389	3.00 / 20.7	8.25 / 56.9	8.87 / 61.2	1.98 / 13.7	470 / 3241	452 / 3116	0.0697	0.0957
3	67.5 / 465	59.7 / 412	2.80 / 19.3	7.78 / 53.6	8.37 / 57.7	1.68 / 11.6	467 / 3220	452 / 3116	0.054	0.113
4	66.7 / 460	47.4 / 327	2.85 / 19.7	8.00 / 55.2	8.92 / 61.5	1.56 / 10.8	447 / 3082	431 / 2972	0.0553	0.106
5	67.7 / 467	47.1 / 325	2.93 / 20.2	7.81 / 53.8	9.31 / 64.2	1.76 / 12.1	441 / 3041	464 / 3199	0.03	0.136
Average	**68.2 / 470**	**51.8 / 357**	**2.91 / 20.1**	**8.01 / 55.2**	**8.59 / 59.2**	**1.75 / 12.1**	**452 / 3116**	**446 / 3075**	**0.0513**	**0.108**
Std. Dev.	1.27 / 8.76	5.86 / 40.4	.08 / .55	.22 / 1.5	.71 / 4.9	.16 / 1.1	15.4 / 106	14.5 / 100	0.0144	0.019
C.O.V. (%)	2	11	3	3	8	9	3	3	28	17

Table 9: Mechanical properties for panel 004

3Tex Panel 005	Tensile Strength (TS) 0°* (KSI/MPa)	TS 90°	TS Through Thickness (TT) **	Young's Modulus (*E*) 0° (MSI/GPa)	*E* 90°	*E* TT	Shear Modulus (*G*) 0° (KSI/MPa)	*G* 90°	Poisson's Ratio (*v*) 0° (%)	*v* 90°
1	64.9 / 447	49.7 / 343	2.64 / 18.2	11.0 / 75.8	10.1 / 69.6	2.08 / 14.3	449 / 3096	526 / 3627	0.0446	0.064
2	72.8 / 502	52.4 / 361	2.54 / 17.5	10.9 / 75.2	10.8 / 74.5	1.87 / 12.9	351 / 2420	497 / 3427	0.0638	0.0542
3	74.6 / 514	49.6 / 342	2.54 / 17.5	10.8 / 74.5	10.3 / 71.0	1.91 / 13.2	518 / 3571	511 / 3523	0.0498	0.044
4			2.43 / 16.8			1.96 / 13.5	500 / 3447	529 / 3647		
5			2.32 / 16.0			1.87 / 12.9		506 / 3489		
Average	**70.8 / 488**	**50.6 / 349**	**2.49 / 17.2**	**10.9 / 75.2**	**10.4 / 71.7**	**1.94 / 13.4**	**455 / 3137**	**514 / 3544**	**0.0527**	**0.0541**
Std. Dev.	5.16 / 35.6	1.59 / 11	.122 / .841	.10 / .69	.36 / 2.5	.09 / .60	74.9 / 516	13.5 / 93	0.0099	0.01
C.O.V. (%)	7	3	5	1	3	5	16	3	19	18

Table 10: Mechanical properties for panel 005

3Tex Panel 006	Tensile Strength (TS) 0°* (KSI/MPa)	TS 90°	TS Through Thickness (TT) **	Young's Modulus (*E*) 0° (MSI/GPa)	*E* 90°	*E* TT	Shear Modulus (*G*) 0° (KSI/MPa)	*G* 90°	Poisson's Ratio (*v*) 0° (%)	*v* 90°
1	70.0 / 483	48.7 / 336	2.30 / 15.9	10.8 / 74.5	10.7 / 73.8	1.95 / 13.4	413 / 2848	413 / 2848	0.0665	0.0535
2	75.1 / 518	46.6 / 321	2.53 / 17.4	11.0 / 75.8	11.1 / 76.5	1.94 / 13.4	394 / 2717	391 / 2696	0.0456	0.0579
3	71.1 / 490	44.2 / 305	2.57 / 17.7	10.6 / 73.1	10.9 / 75.2	2.04 / 14.1	381 / 2627	383 / 2641	0.0405	0.0602
4	73.7 / 508	42.0 / 290	2.53 / 17.4	10.7 / 73.8	10.9 / 75.2	2.10 / 14.5	358 / 2468	382 / 2634	0.0454	0.0529
5	75.4 / 520	43.3 / 299	2.40 / 16.5	10.4 / 71.7	10.7 / 73.8	2.07 / 14.3	394 / 2717	375 / 2586	0.0586	0.0449
6	73.9 / 510			11.0 / 75.8					0.0503	
Average	**73.2 / 505**	**45.0 / 310**	**2.47 / 17.0**	**10.8 / 74.5**	**10.9 / 75.2**	**2.02 / 13.9**	**388 / 2675**	**389 / 2682**	**0.0512**	**0.0539**
Std. Dev.	2.2 / 15	2.7 / 19	.113 / .779	.24 / 1.6	.17 / 1.2	.07 / .50	20.3 / 140	14.7 / 101	0.0097	0.0059
C.O.V. (%)	3	6	5	2	2	4	5	4	19	11

Table 11: Mechanical properties for panel 006

Team Panel 007	Tensile Strength (TS) 0°* (KSI/MPa)	TS 90° *	TS Through Thickness (TT) **	Young's Modulus (*E*) 0° (MSI/GPa)	*E* 90°	*E* TT	Shear Modulus (*G*) 0° (KSI/MPa)	*G* 90°	Poisson's Ratio (*v*) 0° (%)	*v* 90°
1	71.5 / 493	62.1 / 428	2.35 / 16.2	7.96 / 54.9	8.48 / 58.5	2.16 / 14.9	450 / 3103	478 / 3296	0.0833	0.0727
2	72.3 / 498	69.5 / 479	2.49 / 17.2	7.91 / 54.5	8.46 / 58.3	1.87 / 12.9	441 / 3041	451 / 3110	0.163	0.0481
3	70.2 / 484	67.0 / 462	2.44 / 16.8	7.79 / 53.7	8.77 / 60.5	1.85 / 12.8	449 / 3096	447 / 3082	0.0877	0.0874
4	71.0 / 490	71.8 / 495	2.44 / 16.8	7.86 / 54.2	8.80 / 60.7	2.01 / 13.9	446 / 3075	431 / 2972	0.112	0.104
5	69.9 / 482	71.8 / 495	2.40 / 16.5	7.87 / 54.3	8.39 / 57.8	1.94 / 13.4	452 / 3116	420 / 2896	0.105	0.0566
6	70.9 / 489	71.3 / 492		8.35 / 57.6	8.56 / 59.0				0.105	0.0581
Average	**71.0 / 490**	**68.9 / 475**	**2.42 / 16.7**	**7.96 / 54.9**	**8.58 / 59.2**	**1.97 / 13.6**	**448 / 3089**	**445 / 3068**	**0.109**	**0.0712**
Std. Dev.	.87 / 6.0	3.8 / 26	0.05 / .34	.20 / 1.4	.17 / 1.2	.13 / .86	4.3 / 30	22 / 152	0.029	0.0213
C.O.V. (%)	1	6	2	3	2	6	1	5	26	30

Table 12: Mechanical properties for panel 007

Team Panel 008	Tensile Strength (TS) 0° (KSI/MPa)	TS 90°	TS Through Thickness (TT) **	Young's Modulus (*E*) 0° (MSI/GPa)	*E* 90°	Shear Modulus (*G*) 0° (KSI/MPa)	*G* 90°	Poisson's Ratio (*v*) 0° (%)	*v* 90°
1	112 / 772	76.6 / 528	2.73 / 18.8	9.00 / 62.1	6.29 / 43.4	516 / 3558	511 / 3523	0.0776	0.0748
2	141 / 972	83.9 / 578	2.63 / 18.1	9.34 / 64.4	6.16 / 42.5	540 / 3723	532 / 3668	0.0859	0.0768
3	123 / 848	89.5 / 617	2.67 / 18.4	8.84 / 61.0	6.07 / 41.9	513 / 3537	502 / 3461	0.0746	0.0617
4	139 / 958	78.2 / 539	2.76 / 19.0	9.32 / 64.3	6.17 / 42.5	531 / 3661	475 / 3275	0.084	0.0643
5	125 / 862	78.6 / 542	2.69 / 18.5	9.21 / 63.5	6.09 / 42.0	480 / 3309	442 / 3047	0.0762	0.0728
6	134 / 924			9.05 / 62.4				0.0839	
Average	**129 / 889**	**81.4 / 561**	**2.70 / 18.6**	**9.13 / 62.9**	**6.16 / 42.5**	**516 / 3558**	**492 / 3392**	**0.0804**	**0.0701**
Std. Dev.	11.0 / 76	5.3 / 37	.05 / .34	.20 / 1.4	.08 / .56	22.9 / 158	34.8 / 240	0.0048	0.0067
C.O.V. (%)	9	7	2	2	1	4	7	6	10

Table 13: The mechanical properties of panel 008.

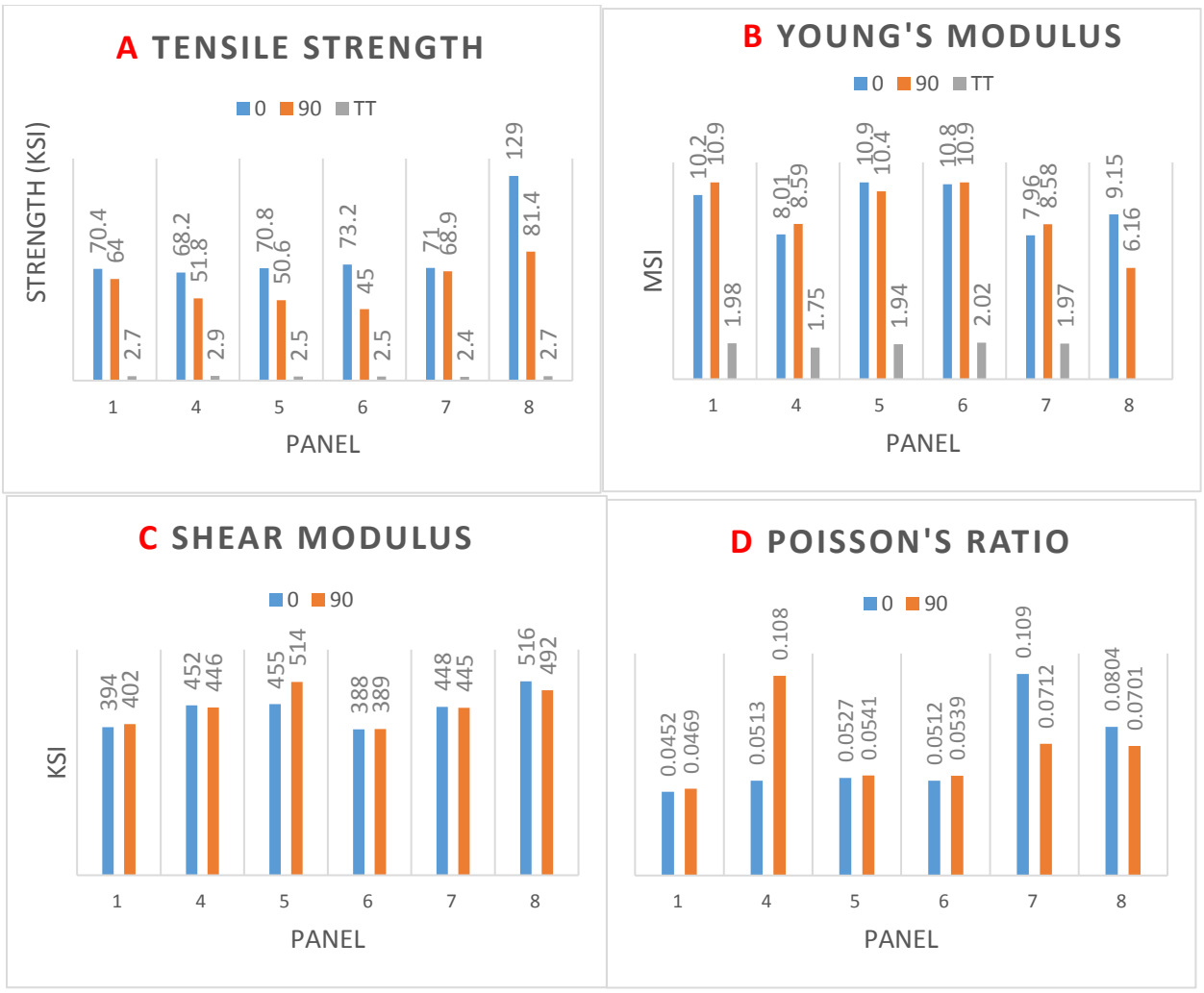


Figure 2: A comparison of each panel's mechanical properties (A) Tensile Strength (B) Young's Modulus (C) Shear Modulus (D) Poisson's Ratio.

Conclusion

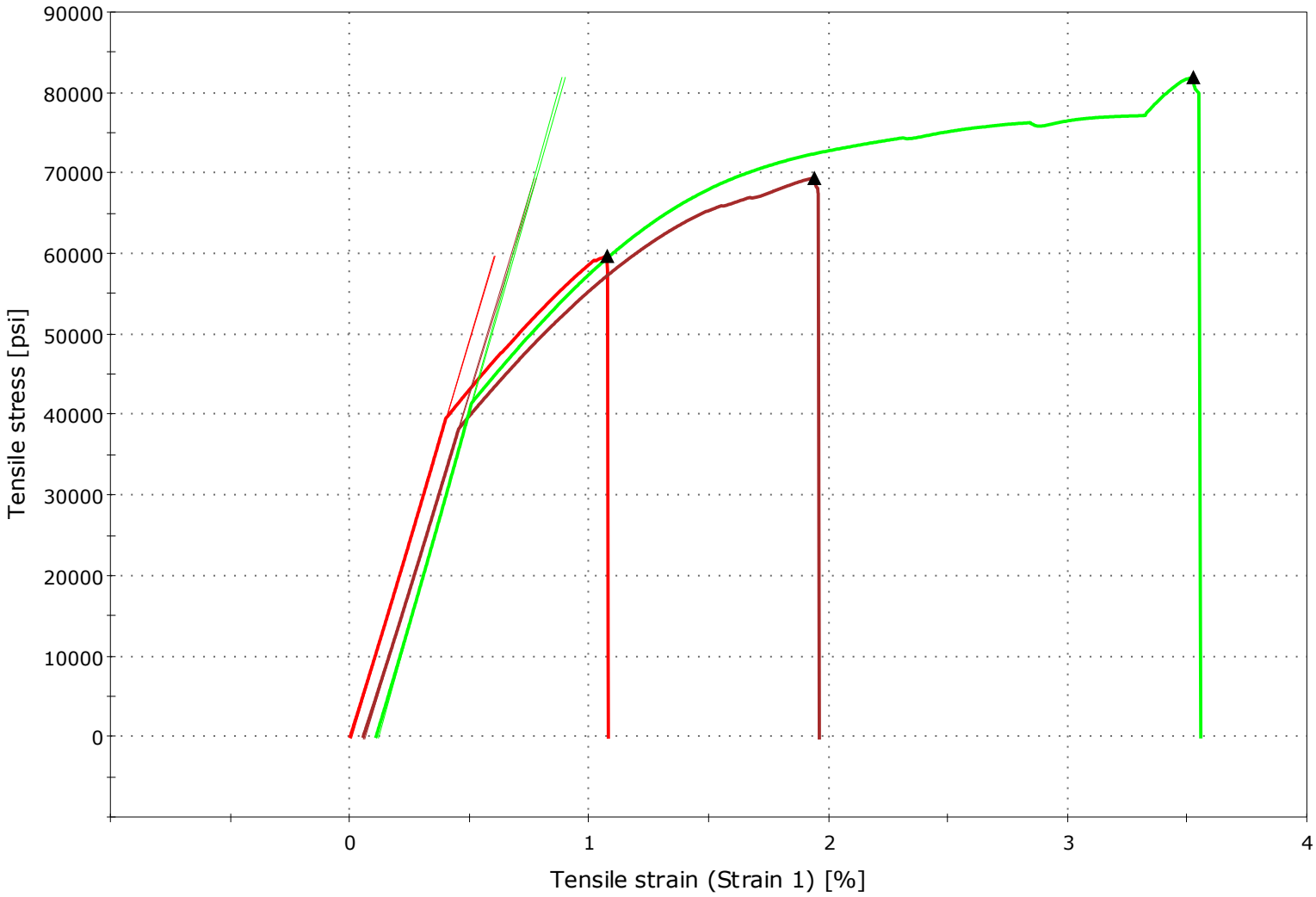
Additional mechanical testing of the 3D woven carbon composite panels is required. Most of the tests performed on the 3D woven carbon composites suffered from either grip slippage or adhesive failure. As a result, it is unlikely that the quantitative properties accurately reflect those of the panels. To attain accurate measurements, stronger grips and adhesives will need to be used in future testing. Another solution would be to weave thinner panels, or section them into narrower "dog bones" for testing.

References

1. Mohamed, M., and Wetzel, K., "3D Woven Carbon/Glass Hybrid Spar Cap for Wind Turbine Rotor Blade," *Journal of Solar Engineering: Volume 128,* November 2006, pp. 562-573.
2. In *Tenax Filament Yarn*. Retrieved from https://www.tohotenax.com/products/tenax%c2%ae-carbon-fiber/tenax%c2%ae-filament-yarn/
3. T700S Data Sheet. In *Torayca*. Retrieved from http://www.toraycfa.com/pdfs/T700SDataSheet.pdf
4. CPD Tooling Products Guide. In *epoxi*. Retrieved from https://www.epoxi.com/composite-polymer-design

Appendix I

P20170093, ASTM D3039, MPT-007-006-001, 0°



Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**	
Test Method	:	ASTM D3039/D3039M-14	Purchase Order #: 4601885344
Project Number	:	P20170093	Attachments : 1 graph
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M. Brady	
Date	:	January 23, 2017	

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Material / Sample Name	:	**MPT-007-006-004**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2300	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Max Tensile Stress Achieved (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	69700	---	8150000	8220000	0.0476
2	69300	---	8170000	8250000	0.0697
3	67500	---	7720000	7780000	0.0540
4	66700	---	7930000	8000000	0.0553
5	67700	---	7740000	7810000	0.0300
Average	**68200**		**7940000**	**8010000**	**0.0513**
Std. Dev.	1270		215000	221000	0.0144
C.O.V. (%)	2		3	3	28

Note - Due to high load achieved, specimens were slipping in the grips and were unable to break. Maximum Tensile Stress Achieved is reported instead and Elongation at Break unavailable.

Strain measurements beyond modulus or yield (if present) may have been calculated using a software algorithm after extensometer removal.

Note - Specimens contained voids

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 Purchase Order #: 4601885344
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 23, 2017

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Material / Sample Name	:	**MPT-007-006-004**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	1.014	0.3874	No Break
2	10	1.004	0.3885	No Break
3	10	1.003	0.3942	No Break
4	10	1.001	0.3894	No Break
5	10	1.003	0.3937	No Break

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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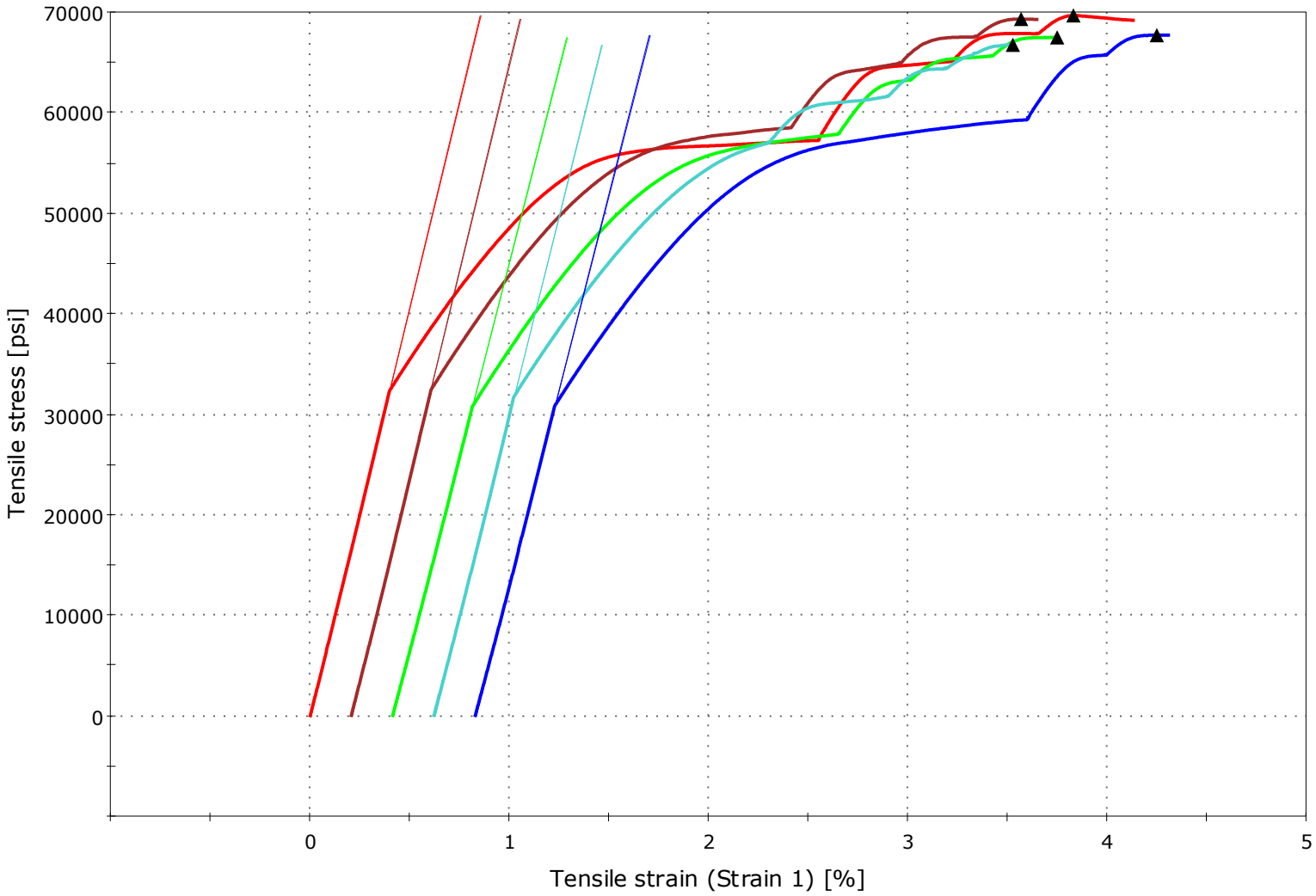

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**	
Test Method	:	ASTM D3039/D3039M-14 - **Modified number of specimens**	
Project Number	:	P20170093	Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs	Attachments : 1 graph
Attention	:	Andrew Littlefield	
Analyst	:	M. Brady	
Date	:	January 23, 2017	

Material / Sample Name	:	**MPT-007-006-005**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2300	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Nominal Tensile Strength (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	64900	---	10800000	11000000	0.0446
2	72800	---	10700000	10900000	0.0638
3	74600	---	10500000	10800000	0.0498
Average	**70800**		**10700000**	**10900000**	**0.0527**
Std. Dev.	5160		153000	100000	0.0099
C.O.V. (%)	7		1	1	19

Note - Due to high load achieved, specimens were slipping in the grips. Tensile Strengths are approximate and Elongation at Break unavailable.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 - **Modified number of specimens**
Project Number	:	P20170093 Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 23, 2017

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Material / Sample Name	:	**MPT-007-006-005**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	1.004	0.3289	LIB
2	10	1.005	0.3313	LIB
3	10	1.007	0.3312	LIB

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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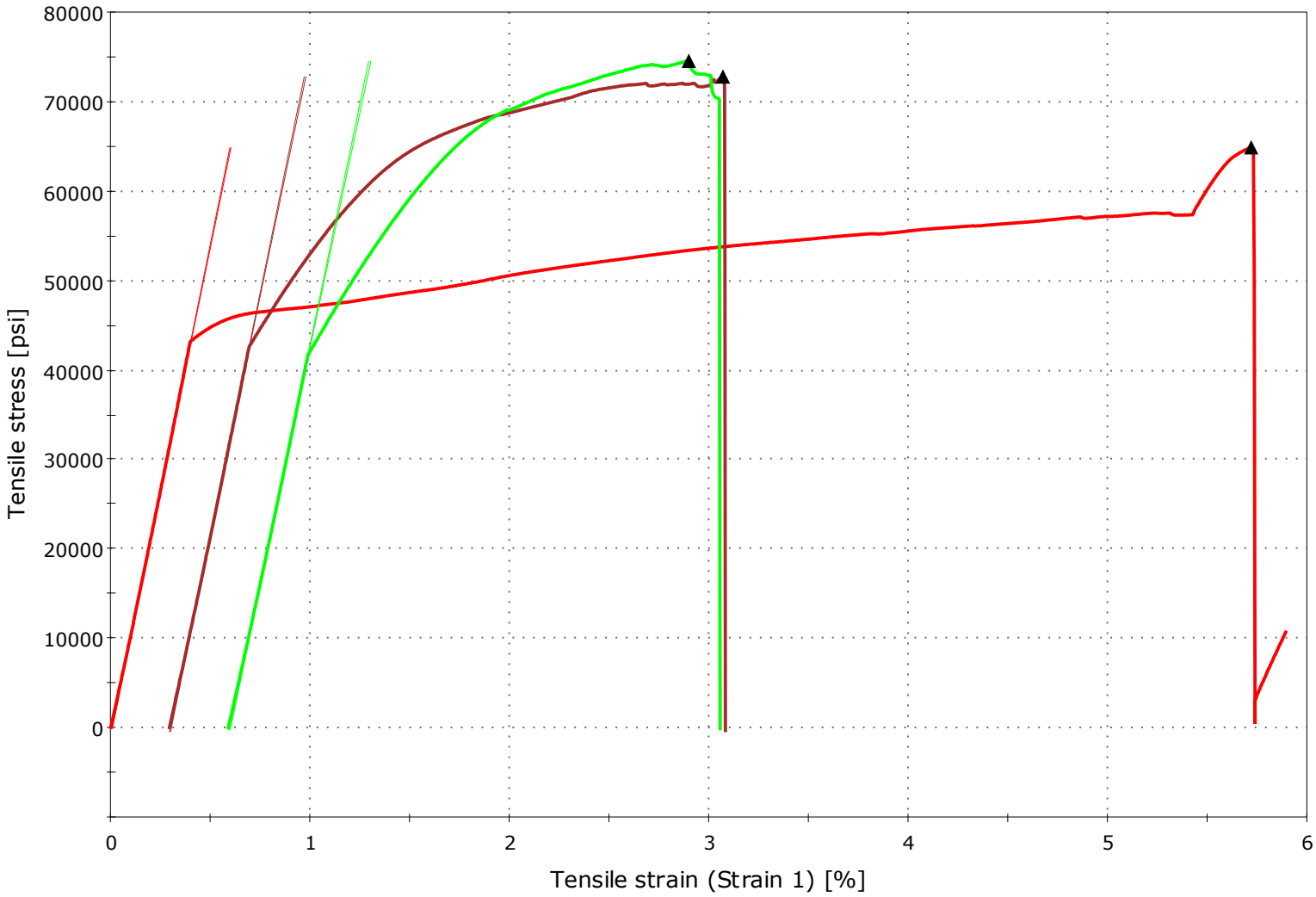

Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 - **Modified thickness variation** [1]
Project Number	:	P20170093 — Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs — Attachments : 1 graph
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

Material / Sample Name	:	**MPT-007-006-006**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**
Average Ply Thickness	:	Not provided
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1) — Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1) — Calibration Date : October 2016
Instron Model Number	:	5985 — Calibration Date : January 2017
Measurement Equipment	:	308 — Calibration Date : January 2017
Measurement Equipment	:	648, 649 — Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit
Grip Pressure (PSI)	:	2300
Alignment Results / Date	:	< 8% / January 16, 2017
Sampling Rate (data points/s)	:	20
Cross-Head Speed	:	0.05 in/min
Conditioning	:	Unconditioned
Moisture Content	:	Unknown
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.

Test Number	Max Stress Achieved (PSI)	Tensile Strength (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	70000	---	---	10600000	10800000	0.0665
2[1]	75100	---	---	10700000	11000000	0.0456
3	---	71100	---	10400000	10600000	0.0405
4	---	73700	---	10500000	10700000	0.0454
5	75400	---	---	10200000	10400000	0.0586
6	---	73900	---	10900000	11000000	0.0503
Average	**73500**	**72900**		**10600000**	**10800000**	**0.0512**
Std. Dev.				243000	235000	0.0097
C.O.V. (%)				2	2	19

Note - Due to high load achieved, all specimens slipped in the grips. Tensile Strength is approximate and Elongation at Break unavailable.

Strain measurements beyond modulus or yield (if present) may have been calculated using a software algorithm after extensometer removal.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 - **Modified thickness variation** [1]
Project Number	:	P20170093 Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

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Material / Sample Name	:	**MPT-007-006-006**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	1.001	0.3929	No Break
2[1]	10	1.001	0.3841	No Break
3	10	1.003	0.3829	LIT
4	10	1.002	0.3812	LIT
5	10	1.003	0.3836	No Break - Maxed Grip Capabilities
6	10	1.002	0.3740	LIT

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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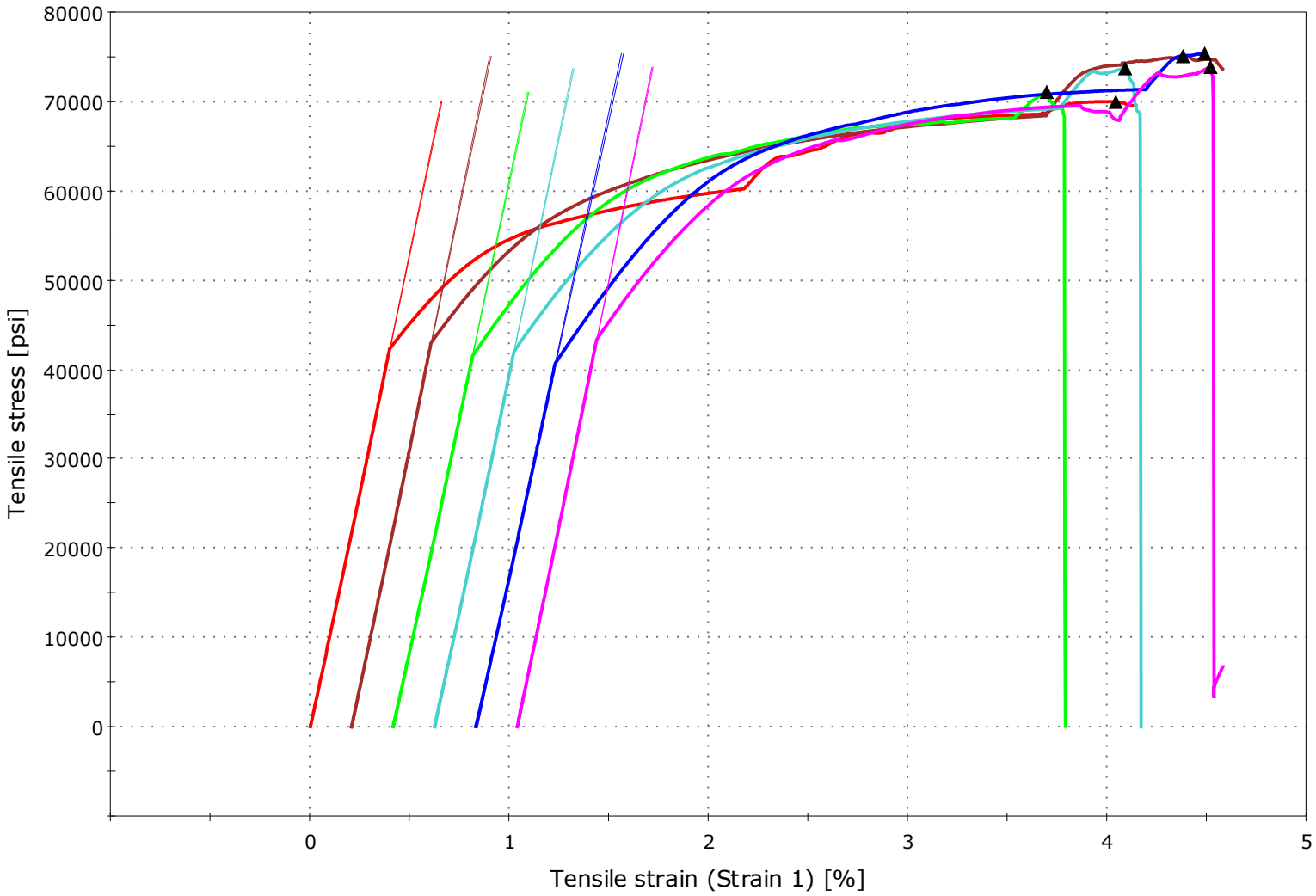

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

Purchase Order #: 4601885344
Attachments : 1 graph

Accredited Nadcap Non Metallic Materials Testing

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Material / Sample Name	:	**MPT-007-006-007**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2300	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Max Stress Achieved (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	71500	---	7890000	7960000	0.0833
2	72300	---	7850000	7910000	0.163
3	70200	---	7720000	7790000	0.0877
4	71000	---	7800000	7860000	0.112
5	69900	---	7790000	7870000	0.105
6	70900	---	8310000	8350000	0.105
Average	**71000**		**7890000**	**7960000**	**0.109**
Std. Dev.	871		212000	201000	0.029
C.O.V. (%)	1		3	3	26

Note - Due to high load achieved, all specimens slipped in the grips. Tensile Strength is approximate and Elongation at Break unavailable.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

Purchase Order #: 4601885344

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Material / Sample Name	:	**MPT-007-006-007**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	1.008	0.4024	No Break - Maxed Grip Capabilites
2	10	1.004	0.3995	No Break - Maxed Grip Capabilites
3	10	1.009	0.4092	No Break - Maxed Grip Capabilites
4	10	1.005	0.4062	No Break - Maxed Grip Capabilites
5	10	1.010	0.4107	No Break - Maxed Grip Capabilites
6	10	1.002	0.4084	No Break - Maxed Grip Capabilites

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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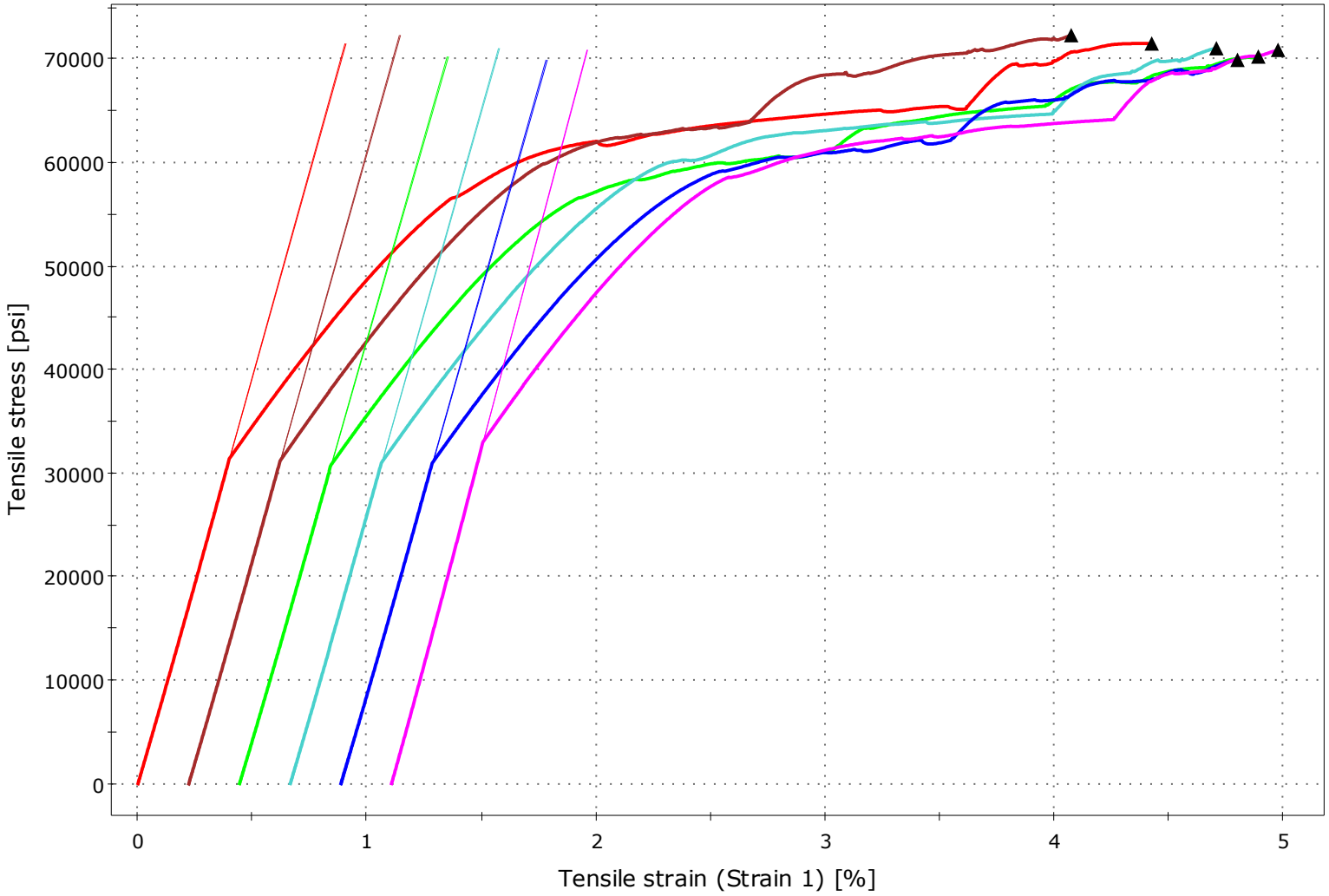

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**	
Test Method	:	ASTM D3039/D3039M-14	Purchase Order #: 4601885344
Project Number	:	P20170093	Attachments : 1 graph
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M. Brady	
Date	:	January 23, 2017	

Material / Sample Name	:	**MPT-007-006-008**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2000	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Tensile Strength (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	112000	---	9000000	9000000	0.0776
2	141000	2.37	9330000	9340000	0.0859
3	123000	2.18	8880000	8840000	0.0746
4	139000	2.34	9350000	9320000	0.0840
5	125000	2.10	9220000	9210000	0.0762
6	134000	2.37	9060000	9050000	0.0839
Average	**129000**	**2.27**	**9140000**	**9130000**	**0.0804**
Std. Dev.	11000	0.12	190000	197000	0.0048
C.O.V. (%)	9	5	2	2	6

Note - The extensometer slipped on specimen 1. Elongation at break unavailable.

Strain measurements beyond modulus or yield (if present) may have been calculated using a software algorithm after extensometer removal.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 23, 2017

Purchase Order #: 4601885344

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Material / Sample Name	:	**MPT-007-006-008**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	1.003	0.1120	LWT
2	10	1.008	0.1077	LAV
3	10	1.004	0.1077	LMV
4	10	1.007	0.1075	M(LA)MV
5	10	1.005	0.1045	LMV
6	10	1.006	0.1099	LAB

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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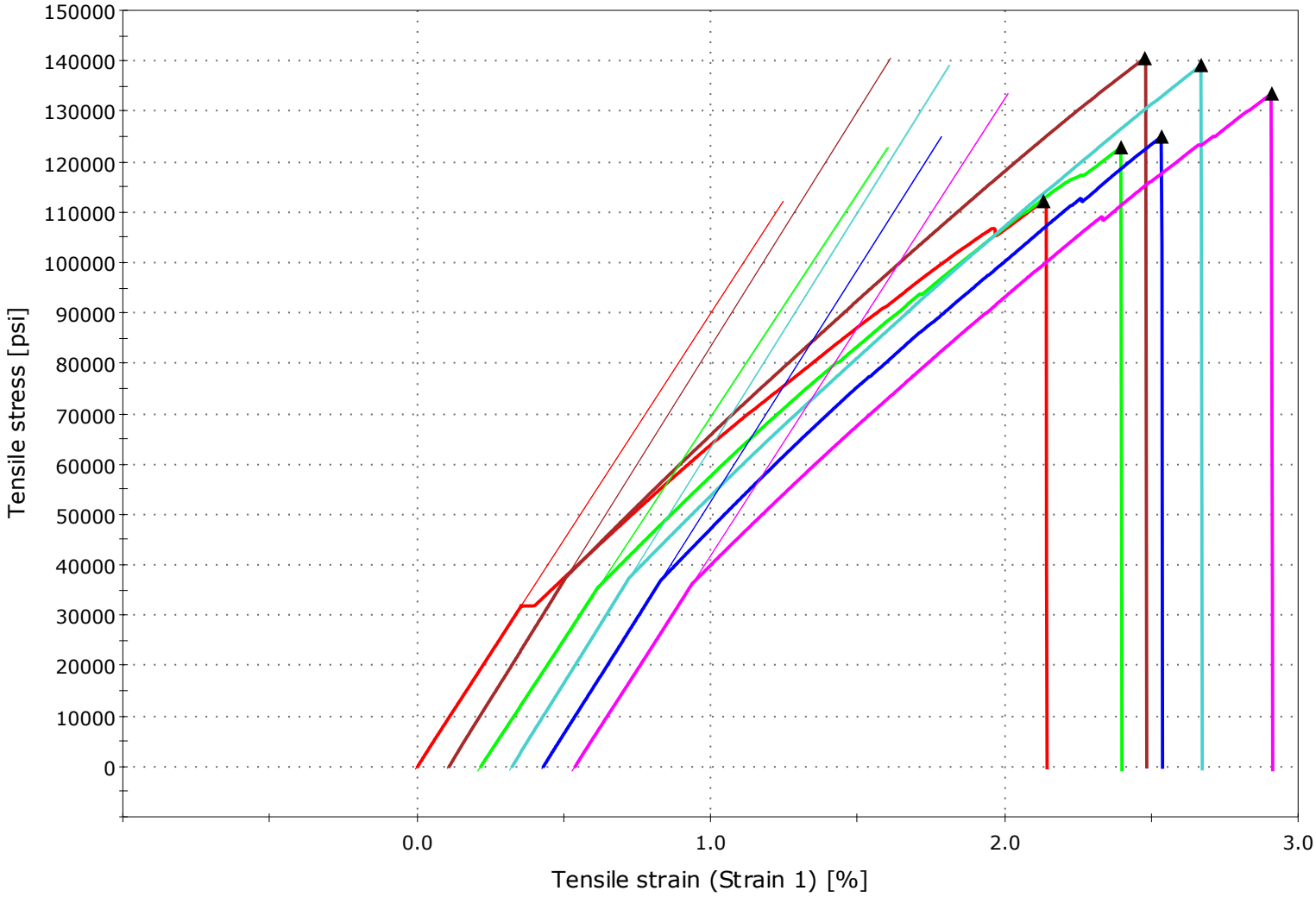

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 - **Modified number of specimens**
Project Number	:	P20170093 — Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs — Attachments : 1 graph
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 25, 2017

Material / Sample Name	:	**MPT-007-006-001**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2300	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Nominal Tensile Strength (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	66100	---	10800000	10900000	0.0507
2	63700	---	10500000	10600000	0.0442
3	62200	---	10800000	11200000	0.0459
Average	**64000**		**10700000**	**10900000**	**0.0469**
Std. Dev.	1970		173000	300000	0.0034
C.O.V. (%)	3		2	3	7

Note - Due to high load achieved, specimens were slipping in the grips. Tensile Strengths are approximate and Elongation at Break unavailable.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 - **Modified number of specimens**
Project Number	:	P20170093 Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 25, 2017

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Material / Sample Name	:	**MPT-007-006-001**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	1.006	0.3361	*
2	10	1.007	0.3364	*
3	10	1.005	0.3354	*

* Specimen ends were crushed by the test grips; no failure in tension.

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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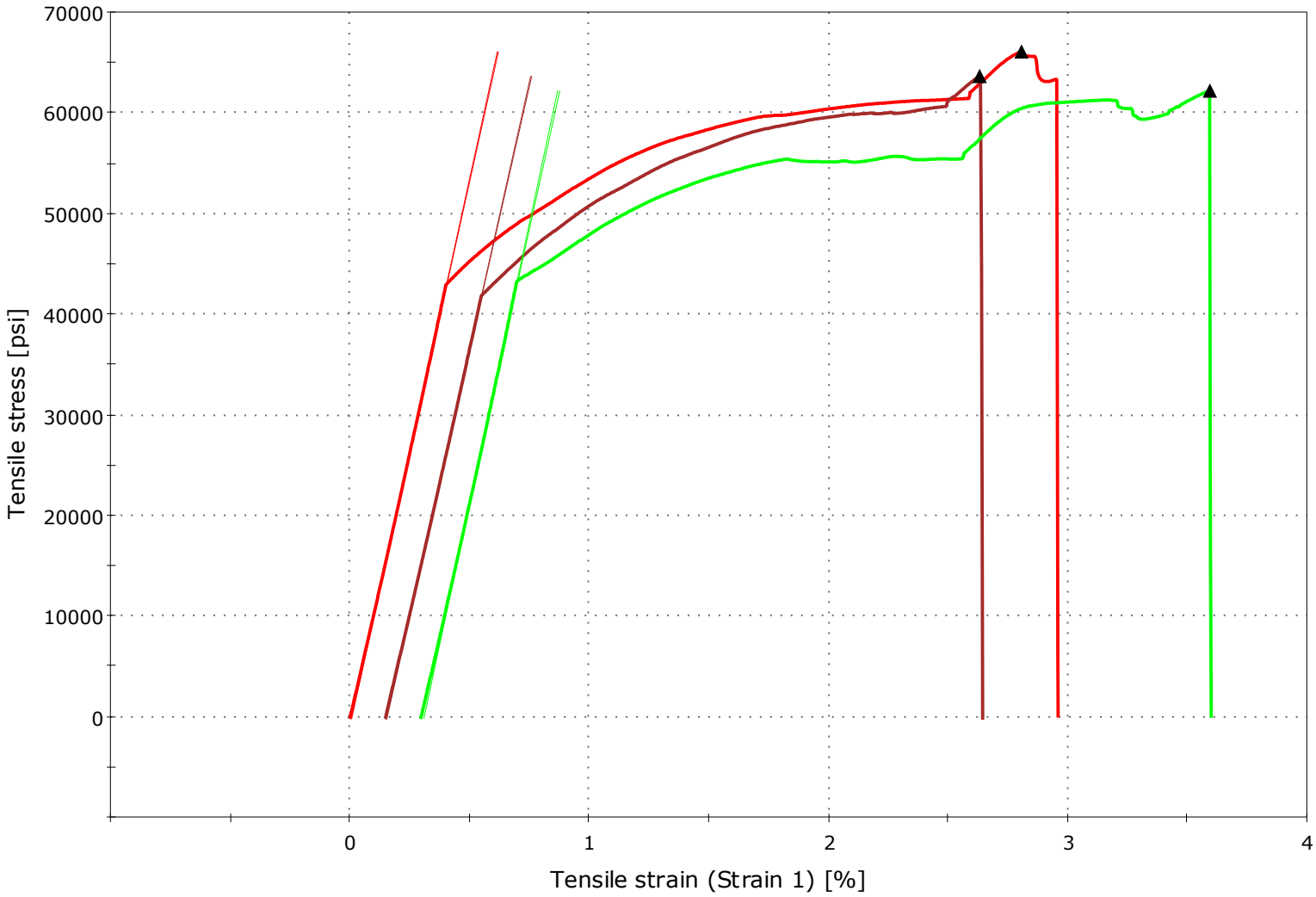
P20170093, ASTM D3039, MPT-007-006-001, 90°



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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093 — Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs — Attachments : 1 graph
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 23, 2017

Accredited Nadcap Non Metallic Materials Testing

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Material / Sample Name	:	**MPT-007-006-004**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2300	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Max Stress Achieved (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	48300	---	7340000	7460000	0.0874
2	56400	---	8740000	8870000	0.0957
3	59700	---	8240000	8370000	0.113
4	47400	---	8650000	8920000	0.106
5	47100	---	8900000	9310000	0.136
Average	**51800**		**8370000**	**8590000**	**0.108**
Std. Dev.	5860		627000	713000	0.019
C.O.V. (%)	11		7	8	17

Note - Due to high load achieved, specimens were slipping in the grips. Maximum Tensile Stress Achieved is reported instead and Elongation at Break unavailable.

Note: specimens contained voids.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 23, 2017

Purchase Order #: 4601885344

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ACCREDITED Cert. No. 0619.01 TESTING LABORATORY

Material / Sample Name	:	**MPT-007-006-004**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	0.988	0.3844	*
2	10	1.003	0.3845	*
3	10	1.002	0.3837	*
4	10	1.003	0.3847	*
5	10	1.013	0.3785	*

* Specimen ends were crushed by the test grips; no failure in tension.

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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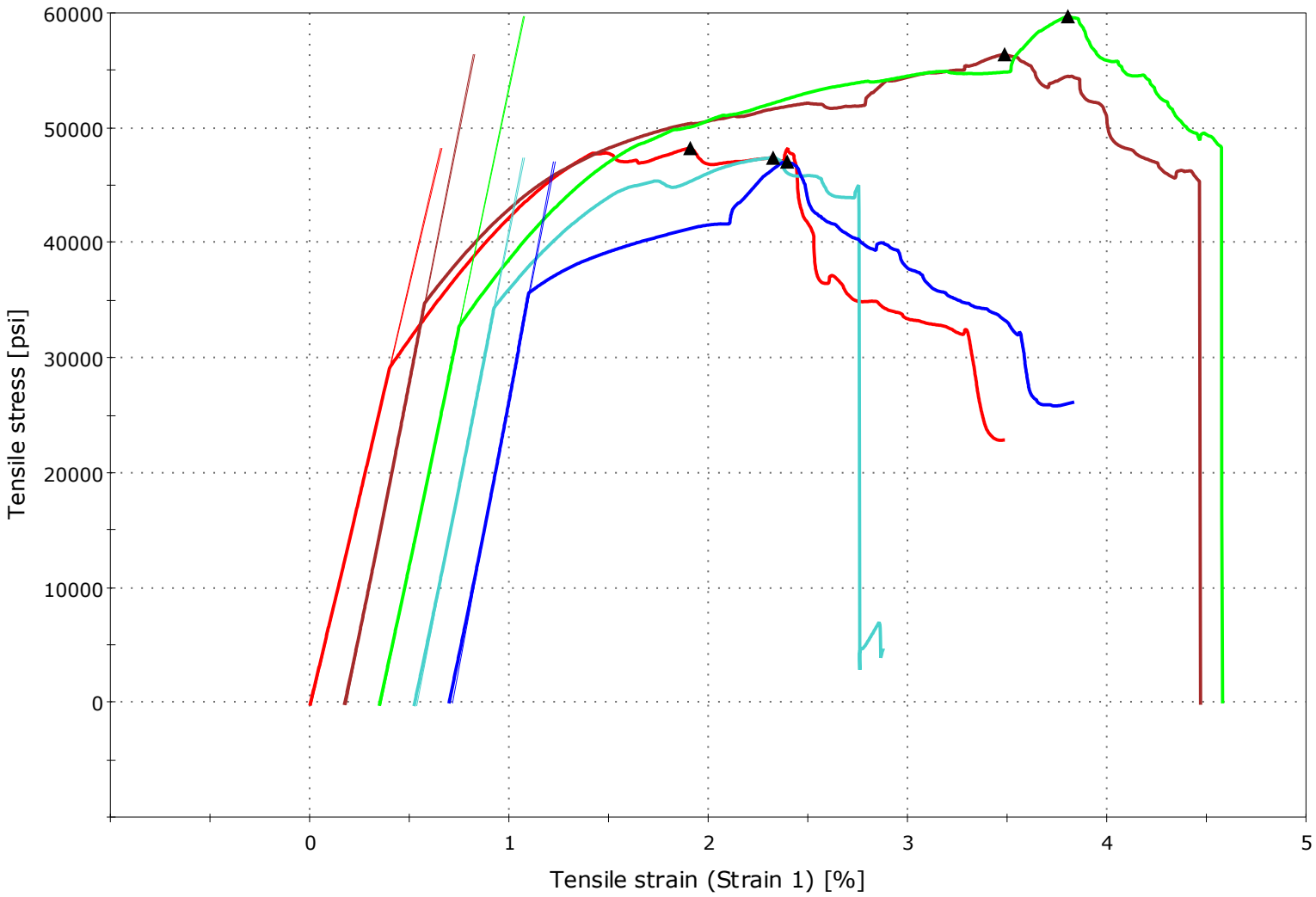
P20170093, ASTM D3039, MPT-007-006-004, 90°



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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 - **Modified number of specimens**
Project Number	:	P20170093 — Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs — Attachments : 1 graph
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 25, 2017

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Material / Sample Name	:	**MPT-007-006-005**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2300	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Tensile Strength (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	49700	1.01	10000000	10100000	0.0640
2	52400	1.27	10600000	10800000	0.0542
3	49600	1.05	10200000	10300000	0.0440
Average	**50600**	**1.11**	**10300000**	**10400000**	**0.0541**
Std. Dev.	1590	0.14	306000	361000	0.0100
C.O.V. (%)	3	13	3	3	18

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14 - **Modified number of specimens**
Project Number	:	P20170093 Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 25, 2017

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Material / Sample Name	:	**MPT-007-006-005**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	0.948	0.3286	GIT
2	10	1.006	0.3303	GIB
3	10	1.007	0.3311	GIT

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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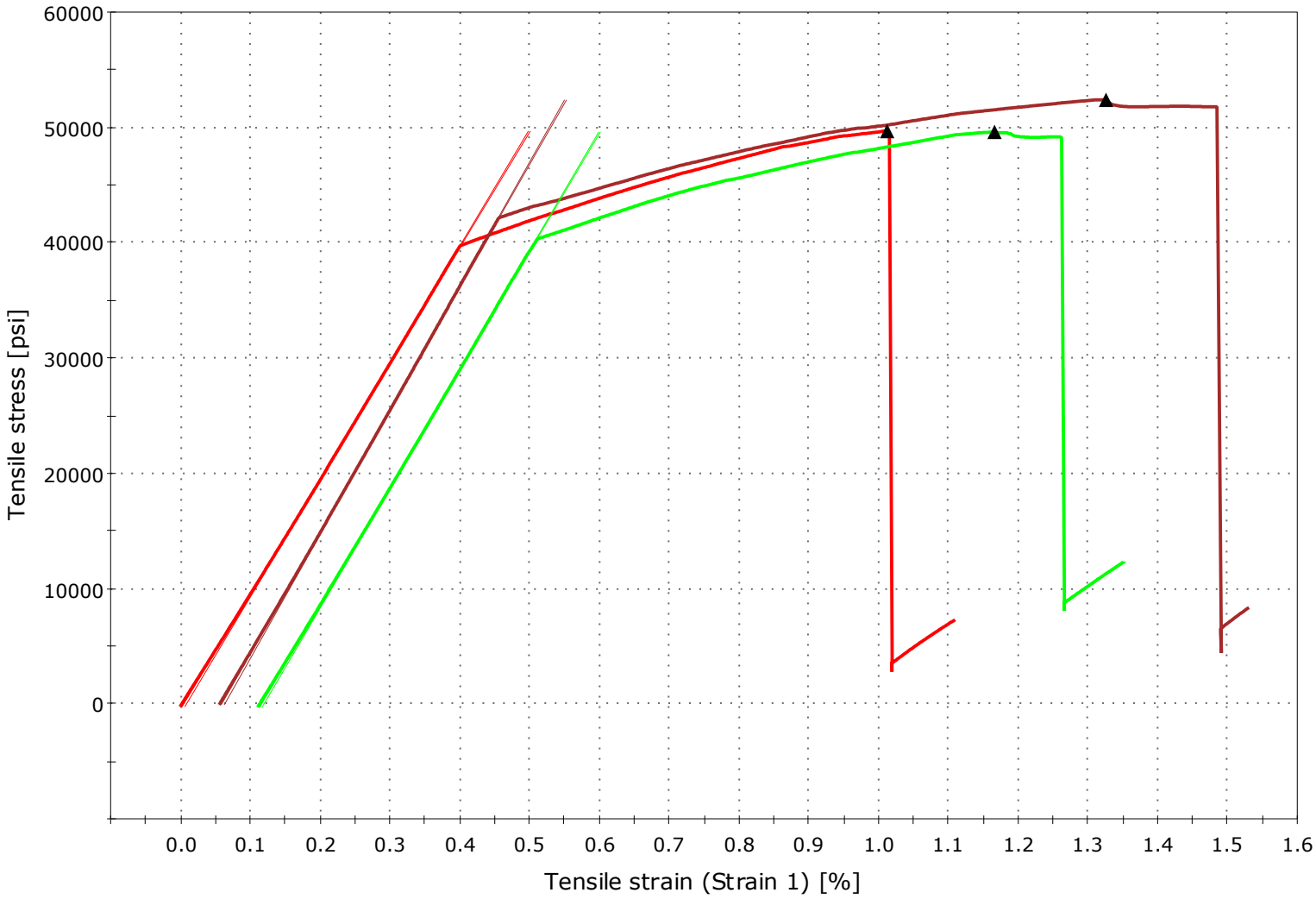
P20170093, ASTM D3039, MPT-007-006-005, 90°



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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093 — Purchase Order #: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs — Attachments : 1 graph
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

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Material / Sample Name	:	**MPT-007-006-006**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**
Average Ply Thickness	:	Not provided
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1) — Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1) — Calibration Date : October 2016
Instron Model Number	:	5985 — Calibration Date : January 2017
Measurement Equipment	:	308 — Calibration Date : January 2017 648, 649 — Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit
Grip Pressure (PSI)	:	2300
Alignment Results / Date	:	< 8% / January 16, 2017
Sampling Rate (data points/s)	:	20
Cross-Head Speed	:	0.05 in/min
Conditioning	:	Unconditioned
Moisture Content	:	Unknown
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.

Test Number	Tensile Strength (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	48700	0.923	10600000	10700000	0.0535
2	46600	0.633	11000000	11100000	0.0579
3	44200	0.472	10900000	10900000	0.0602
4	42000	---	10900000	10900000	0.0529
5	43300	0.491	10600000	10700000	0.0449
Average	**45000**	**0.63**	**10800000**	**10900000**	**0.0539**
Std. Dev.	2680	0.21	187000	167000	0.0059
C.O.V. (%)	6	33	2	2	11

Note - The extensometer slipped on specimen 4 before removal. Elongation at Break unavailable.

Strain measurements beyond modulus or yield (if present) may have been calculated using a software algorithm after extensometer removal.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

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Material / Sample Name	:	**MPT-007-006-006**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	8	1.003	0.3711	LIT
2	8	1.003	0.3818	LIT
3	8	1.002	0.3761	LIT
4	8	1.003	0.3808	LIT
5	8	1.003	0.3793	LIT

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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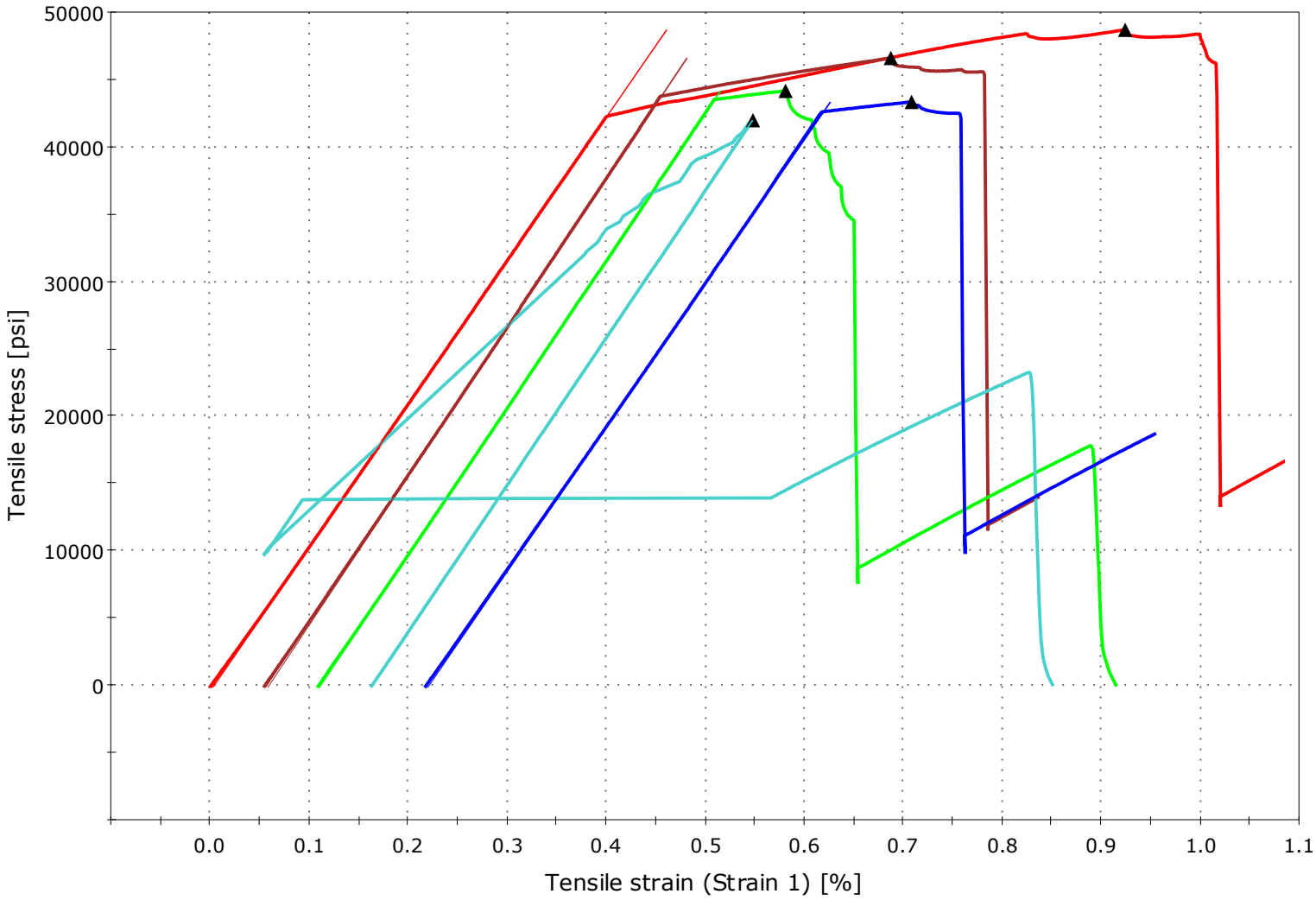
P20170093, ASTM D3039, MPT-007-006-006, 90°



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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

Purchase Order #: 4601885344
Attachments : 1 graph

Accredited Nadcap Non Metallic Materials Testing

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Material / Sample Name	:	**MPT-007-006-007**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2300	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Max Stress Achieved (PSI)	Tensile Strength (PSI)	Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	---	62100	1.82	8470000	8480000	0.0727
2	---	69500	---	8450000	8460000	0.0481
3	---	67000	---	8770000	8770000	0.0874
4	71800	---	---	8800000	8800000	0.104
5	71800	---	---	8370000	8390000	0.0566
6	71300	---	---	8540000	8560000	0.0581
Average	**71600**	**66200**		**8570000**	**8580000**	**0.0712**
Std. Dev.				178000	170000	0.0213
C.O.V. (%)				2	2	30

Note - Due to high load achieved, specimens 2 through 6 slipped in the grips. Tensile Strength is approximate and Elongation at Break unavailable.

Strain measurements beyond modulus or yield (if present) may have been calculated using a software algorithm after extensometer removal.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 24, 2017

Purchase Order #: 4601885344

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Material / Sample Name	:	**MPT-007-006-007**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	10	1.006	0.3956	LIB
2	10	1.004	0.4031	LIB
3	10	1.009	0.4006	LIB
4	10	1.006	0.4017	No Break - Maxed Grip Capabilites
5	10	1.006	0.4014	No Break - Maxed Grip Capabilites
6	10	1.009	0.4029	No Break - Maxed Grip Capabilites

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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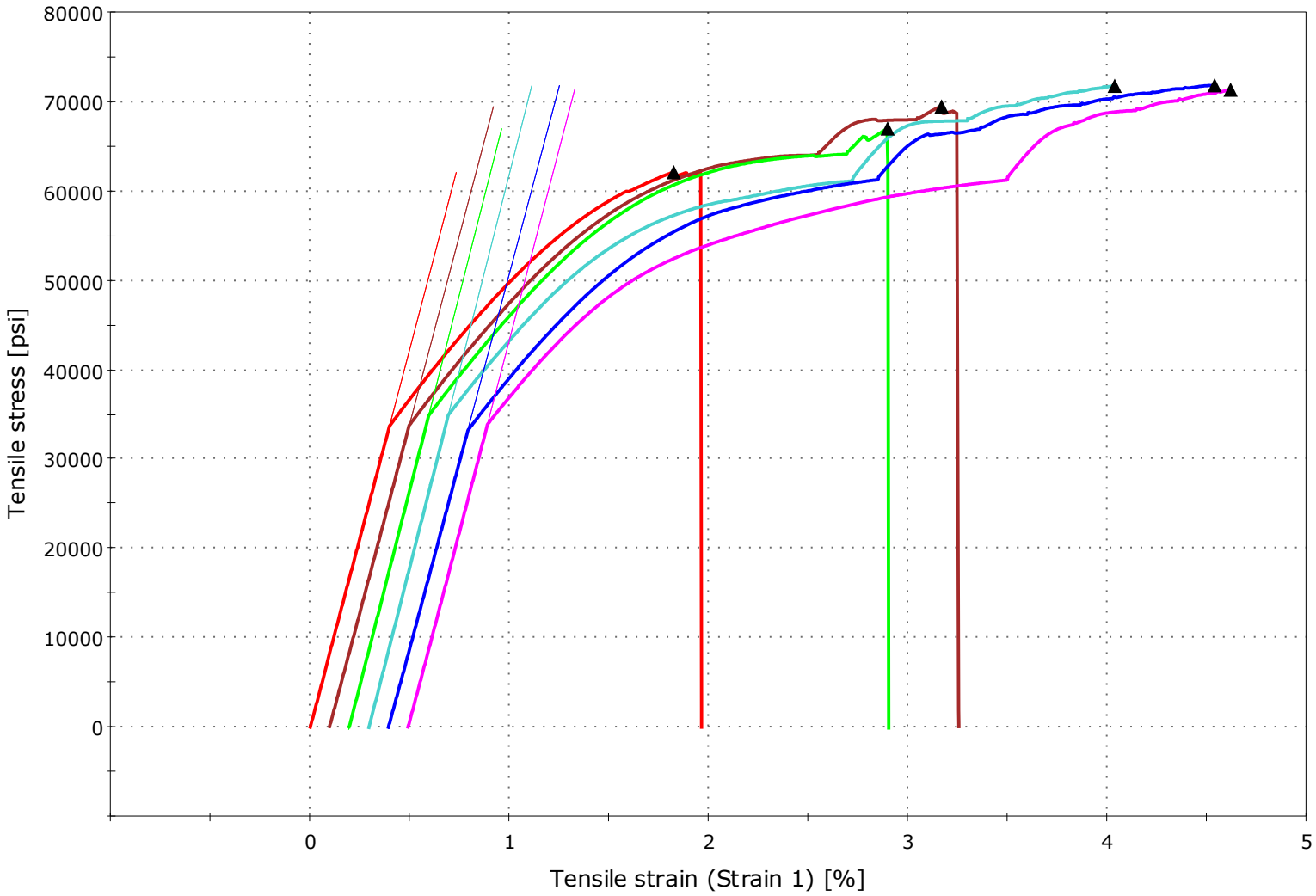
P20170093, ASTM D3039, MPT-007-006-007, 90°



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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**	
Test Method	:	ASTM D3039/D3039M-14	Purchase Order #: 4601885344
Project Number	:	P20170093	Attachments : 1 graph
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M. Brady	
Date	:	January 23, 2017	

Accredited Nadcap Non Metallic Materials Testing

ACCREDITED Cert. No. 0619.01 TESTING LABORATORY

Material / Sample Name	:	**MPT-007-006-008**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness	:	Not provided	
Extensometer (Axial)	:	2% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-1)	Calibration Date : October 2016
Extensometer (Transverse)	:	2% based on 1" gage length (Class B1)	Calibration Date : October 2016
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308	Calibration Date : January 2017
		648, 649	Calibration Date : November 2016
Grip Type / Jaw Type	:	Hydraulic Wedge / abrasive grit	
Grip Pressure (PSI)	:	2000	
Alignment Results / Date	:	< 8% / January 16, 2017	
Sampling Rate (data points/s)	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL using a diamond grit wet saw	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D3039 specifies that strength, elongation, modulus and Poisson's ratio be reported to 3 significant figures.	

Test Number	Tensile Strength (PSI)	Nominal Elongation At Break (%)	Chord Modulus 0.1% - 0.3% (PSI)	Tensile Modulus (Young's) (PSI)	Poisson's Ratio 0.1% - 0.3%
1	76600	2.14	6130000	6290000	0.0748
2	83900	2.11	6210000	6160000	0.0768
3	89500	2.32	6070000	6070000	0.0617
4	78200	2.18	6230000	6170000	0.0643
5	78600	2.01	6050000	6090000	0.0728
Average	**81400**	**2.15**	**6140000**	**6160000**	**0.0701**
Std. Dev.	5310	0.11	80700	86500	0.0067
C.O.V. (%)	7	5	1	1	10

Strain measurements beyond modulus or yield (if present) may have been calculated using a software algorithm after extensometer removal.

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Testing	:	**Tensile Properties of Polymer Matrix Composite Materials**
Test Method	:	ASTM D3039/D3039M-14
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	M. Brady
Date	:	January 23, 2017

Purchase Order #: 4601885344

Accredited Nadcap Non Metallic Materials Testing

ACCREDITED Cert. No. 0619.01 TESTING LABORATORY

Material / Sample Name	:	**MPT-007-006-008**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

Test Number	Length (in)	Width (in)	Thickness (in)	Failure Code
1	7	1.004	0.1063	LAT
2	7	1.006	0.1048	LIT
3	7	1.007	0.1077	LIB
4	7	1.005	0.1077	LIT
5	7	1.008	0.1075	LIT

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside Grip/Tab	I	Bottom	B
Edge Delamination	D	At Grip/Tab	A	Top	T
Grip/Tab	G	<1W From Grip/Tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M (xys)	Multiple Areas	M	Middle	M
Longitudinal Splitting	S	Various	V	Various	V
Explosive	X	Unknown	U	Unknown	U
Other	O				

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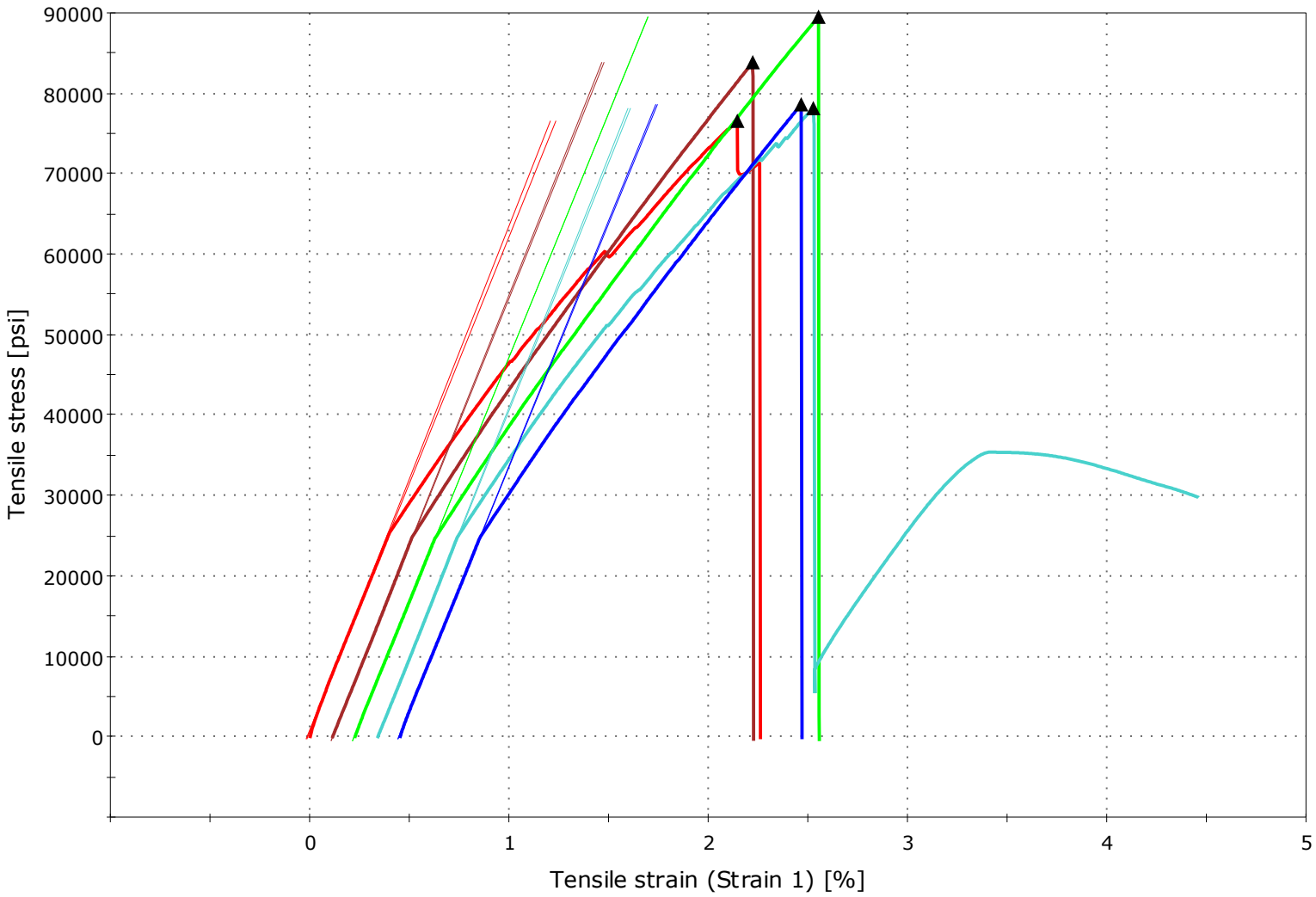
P20170093, ASTM D3039, MPT-007-006-008, 90°



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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 23, 2017	

Material	:	**MPT-007-006-001**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD439	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.190	0.3326	6920	397000	4180	HGN
2	1.191	0.3344	6910	395000	4180	HGN
3	1.190	0.3358	6940	389000	4170	HGN
4	1.194	0.3440	6800	389000	4140	HGN
5	1.195	0.3241	6920	400000	4220	HGN
		Average	**6900**	**394000**	**4180**	
		Std. Dev.	56	4900	29	
		C.O.V. (%)	1	1	1	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 23, 2017

Material	:	**MPT-007-006-001**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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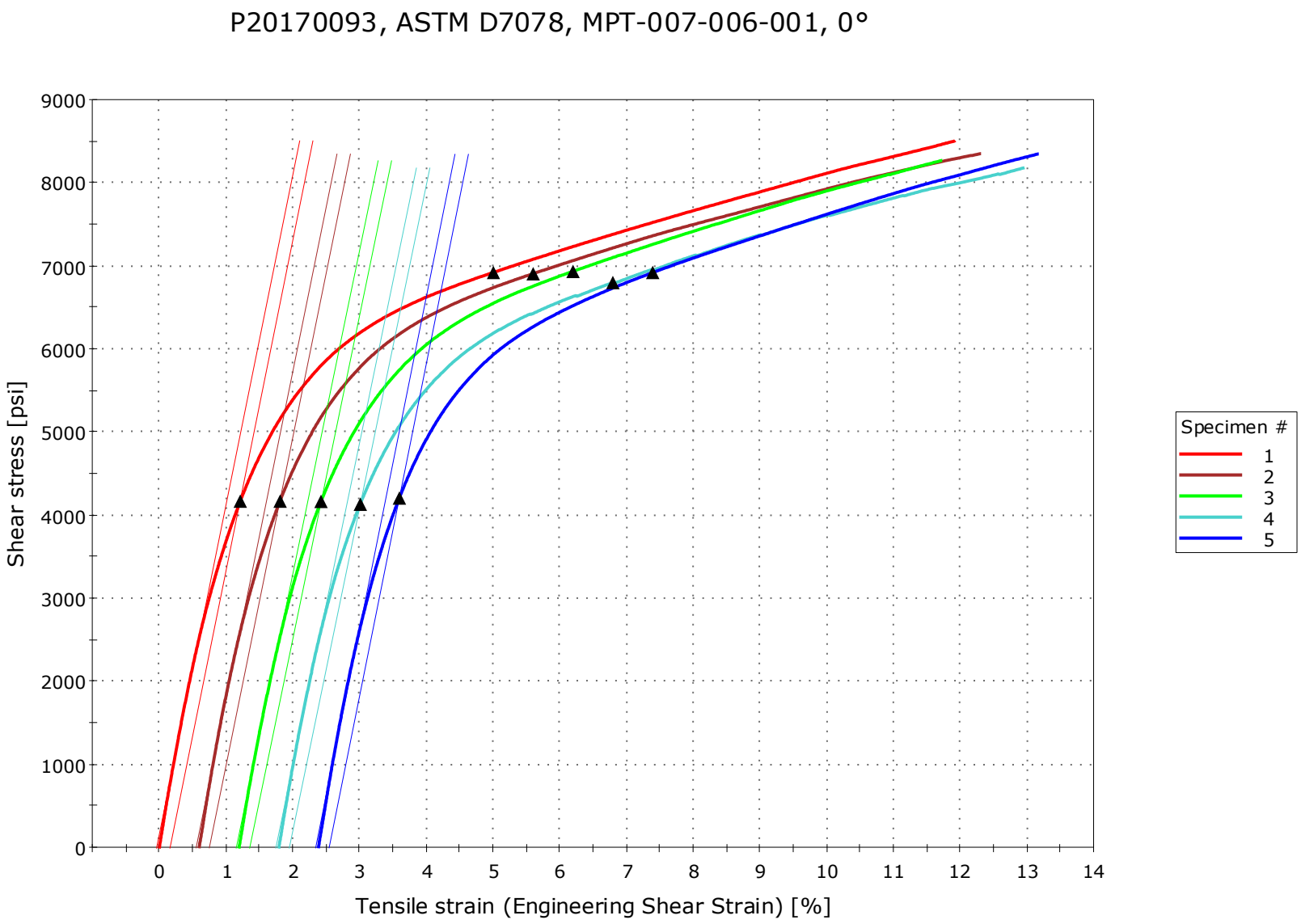
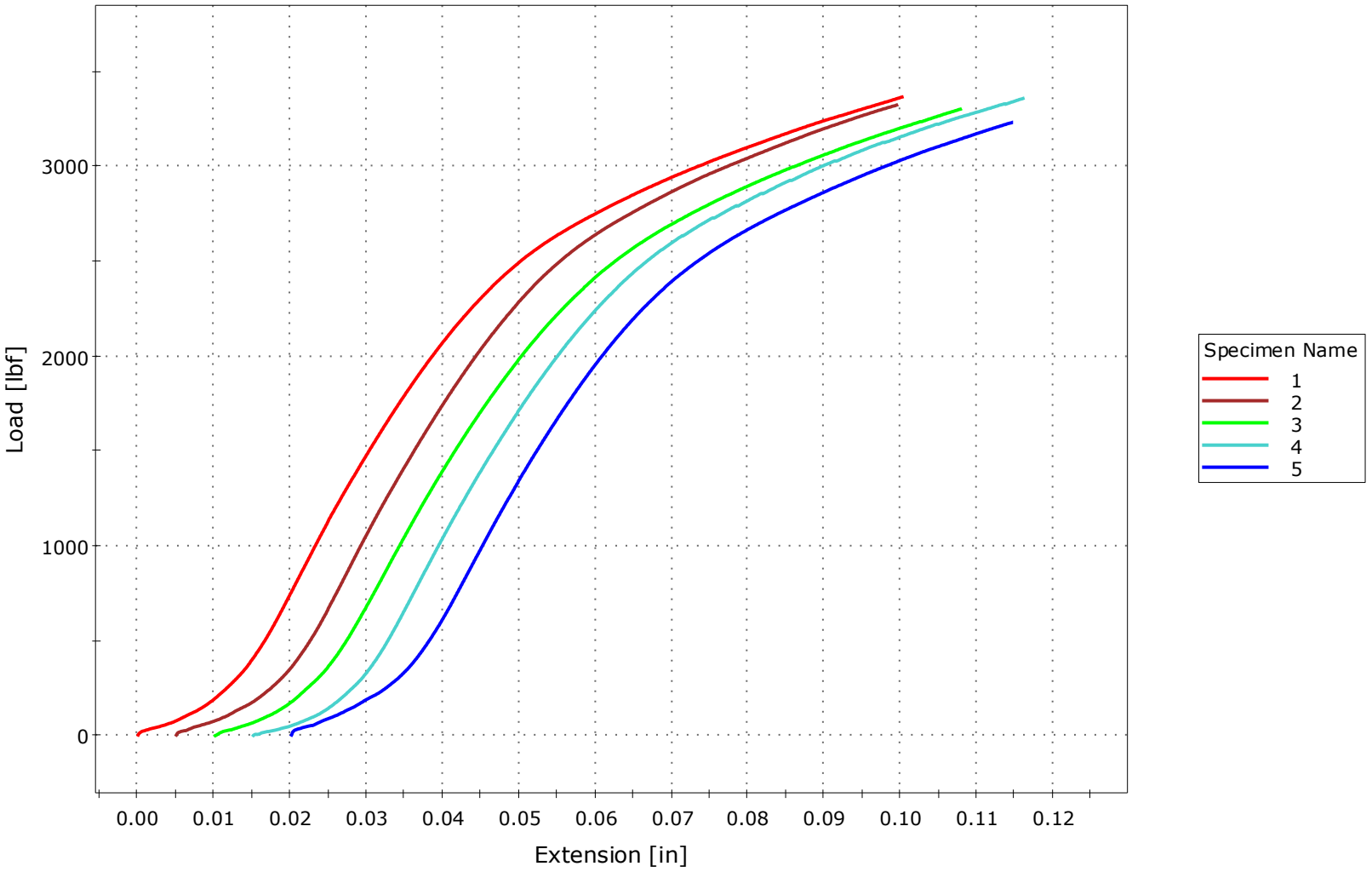


P20170093, ASTM D7078, MPT-007-006-001, 0°



Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 23, 2017	

Material	:	**MPT-007-006-001**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD438	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.203	0.3281	7100	395000	4220	HGN
2	1.197	0.3260	7130	410000	4340	HGN
3	1.196	0.3271	7140	398000	4210	HGN
4	1.194	0.3372	6930	400000	4190	HGN
5	1.198	0.3295	6970	407000	4240	HGN
		Average	**7050**	**402000**	**4240**	
		Std. Dev.	97	6280	59	
		C.O.V. (%)	1	2	1	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 23, 2017

Material	:	**MPT-007-006-001**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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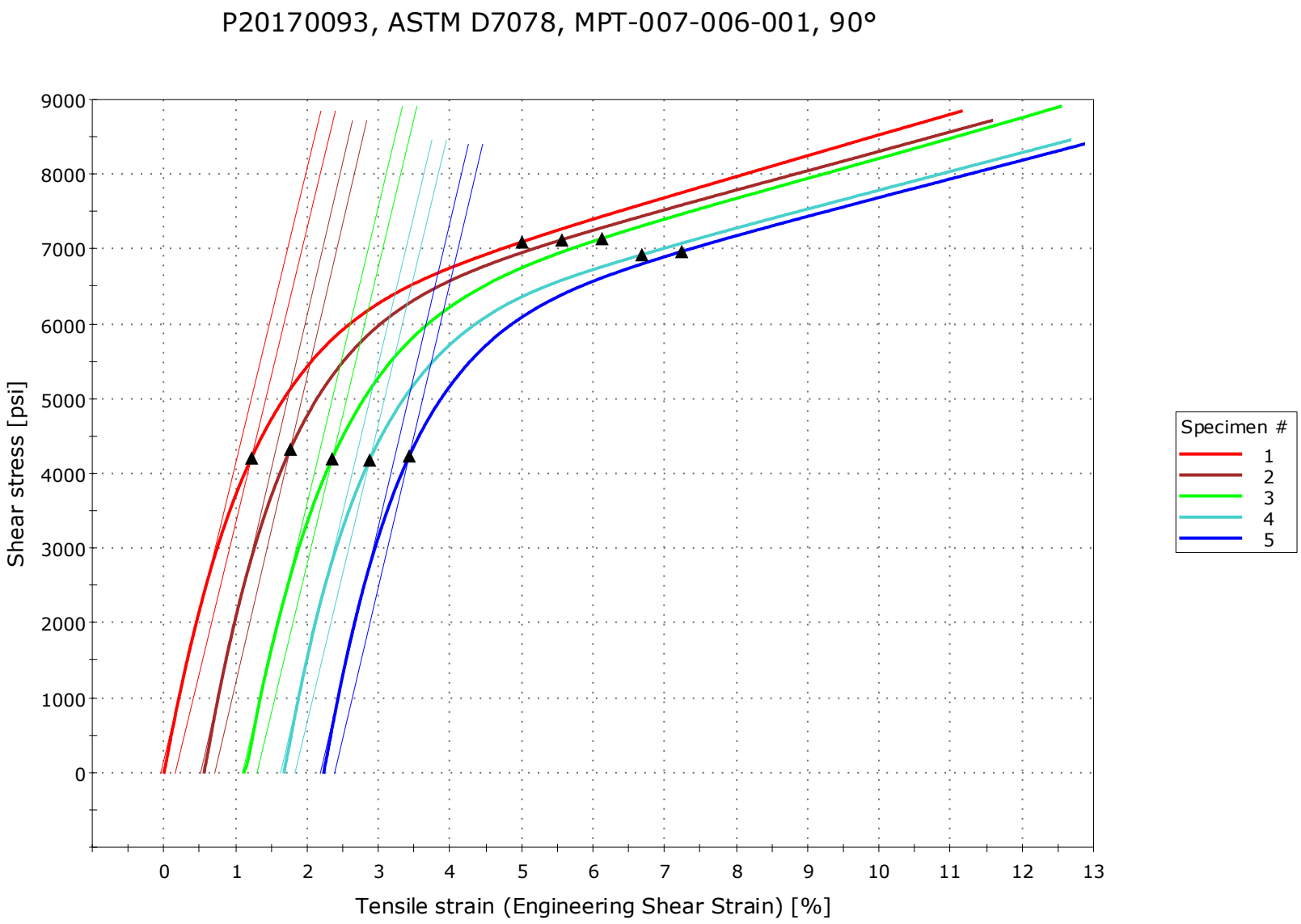

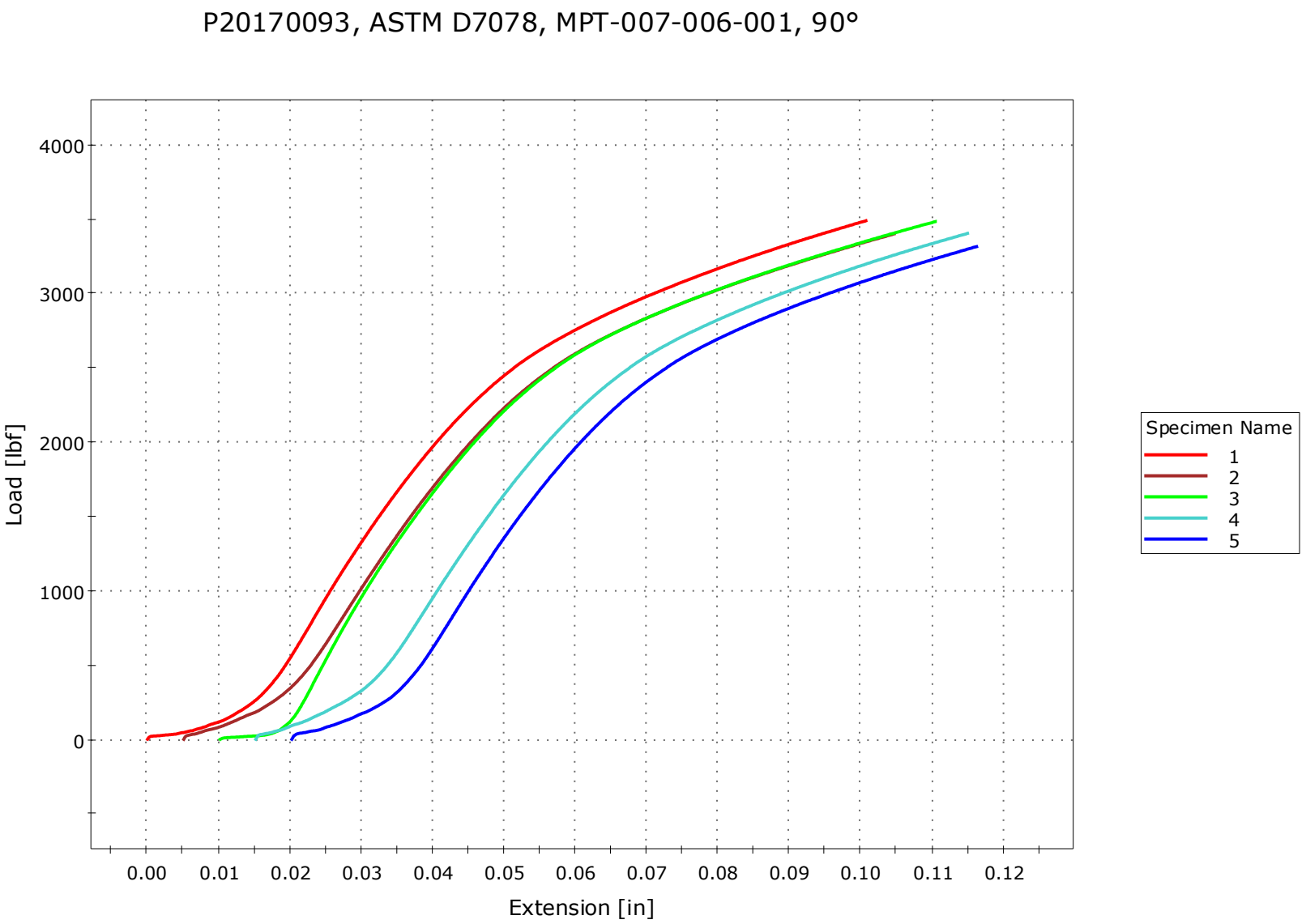

Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 27, 2017	

Material	:	**MPT-007-006-004**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD438	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.207	0.3766	8660	436000	5320	HGN
2	1.203	0.3674	8920	470000	5290	HGN
3	1.198	0.3863	8840	467000	5330	HGN
4	1.201	0.4002	8240	447000	5010	HGN
5	1.193	0.3766	7810	441000	4810	HGN
		Average	**8490**	**452000**	**5150**	
		Std. Dev.	464	15400	232	
		C.O.V. (%)	5	3	5	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 27, 2017

Material	:	**MPT-007-006-004**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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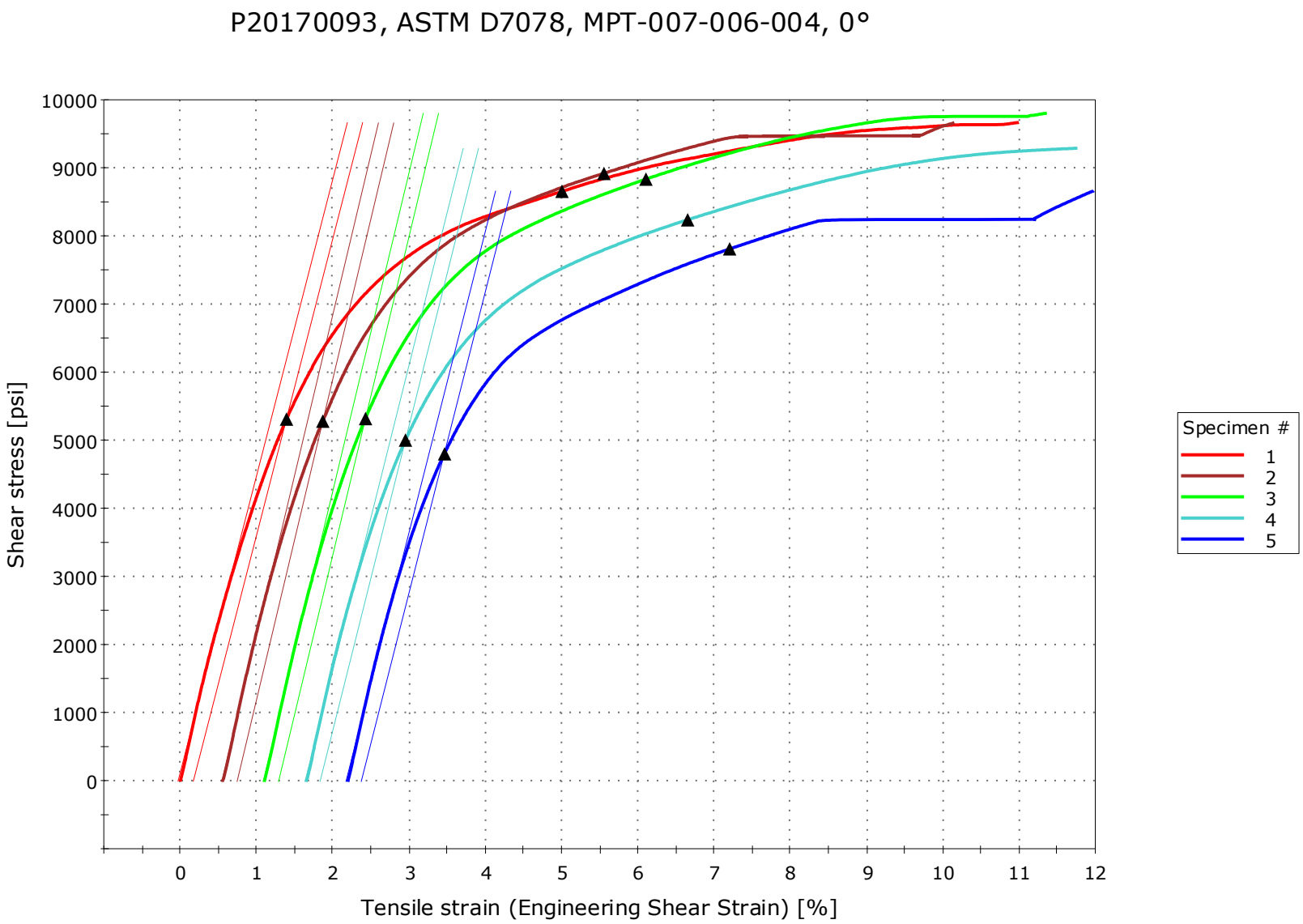

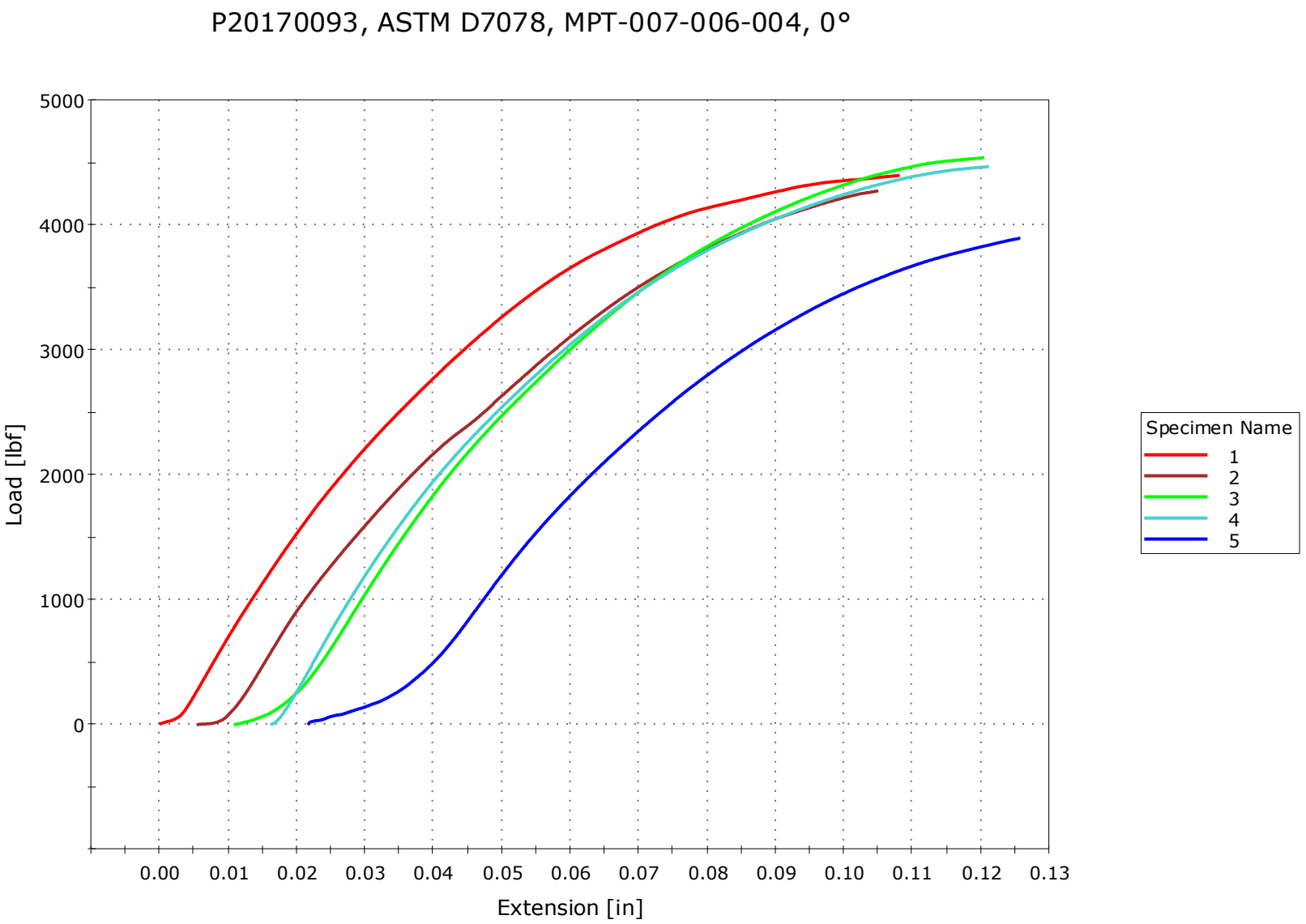

Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 27, 2017	

Material	:	**MPT-007-006-004**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD438	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.203	0.3969	7890	431000	4760	HGN
2	1.200	0.3981	7810	452000	4930	HGN
3	1.201	0.3918	8060	452000	5030	HGN
4	1.205	0.3726	8200	431000	4910	HGN
5	1.205	0.3802	8190	464000	5050	HGN
		Average	**8030**	**446000**	**4940**	
		Std. Dev.	176	14500	116	
		C.O.V. (%)	2	3	2	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 27, 2017

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Material	:	**MPT-007-006-004**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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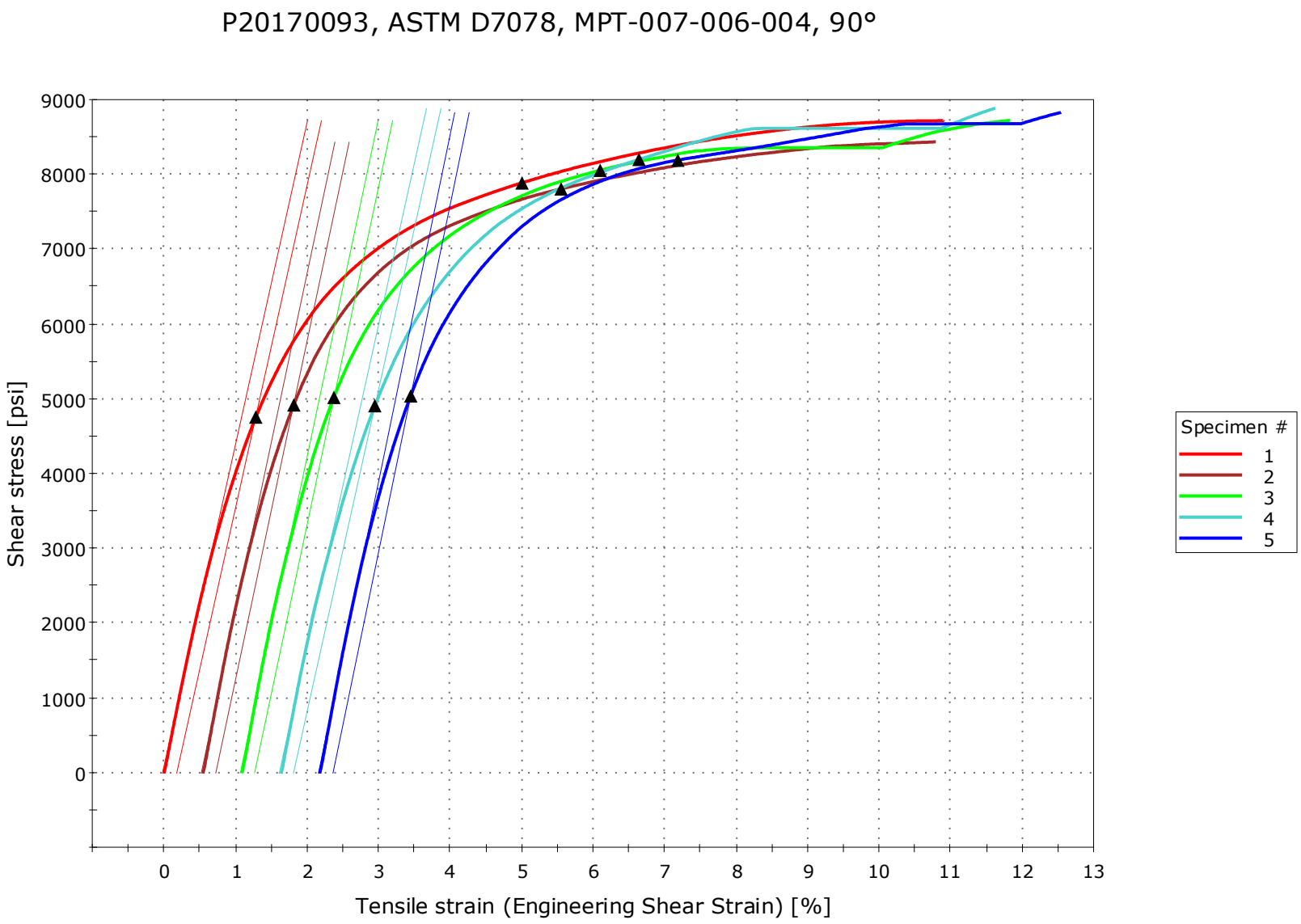

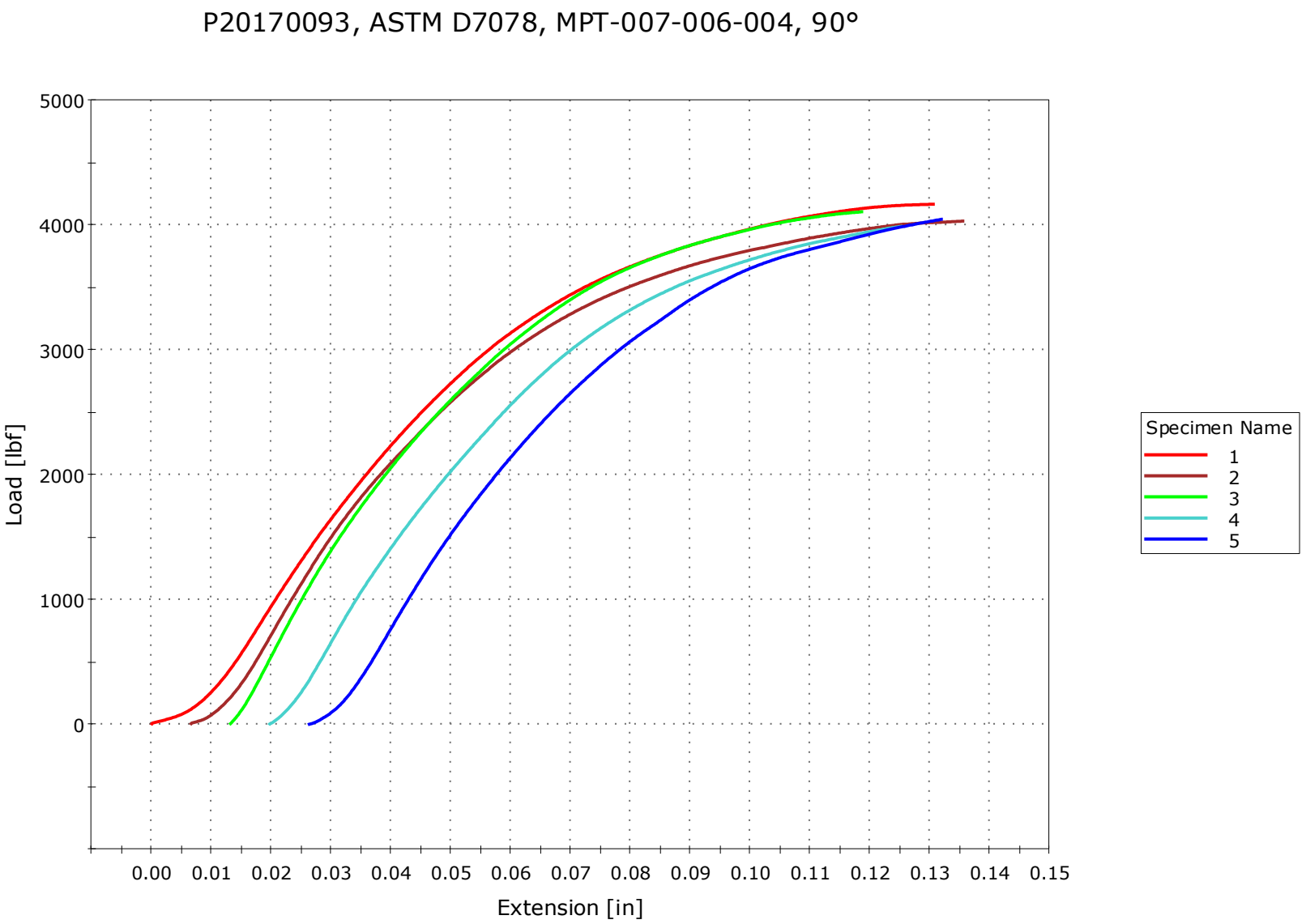

Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 23, 2017	

Material	:	**MPT-007-006-006**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD438	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.196	0.4036	6680	413000	4150	HGN
2	1.195	0.3901	6690	394000	4020	HGN
3	1.194	0.3913	6620	381000	3950	HGN
4	1.191	0.3803	6600	358000	3800	HGN
5	1.197	0.3826	6750	394000	4070	HGN
		Average	**6670**	**388000**	**4000**	
		Std. Dev.	60	20300	133	
		C.O.V. (%)	1	5	3	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 23, 2017

Material	:	**MPT-007-006-006**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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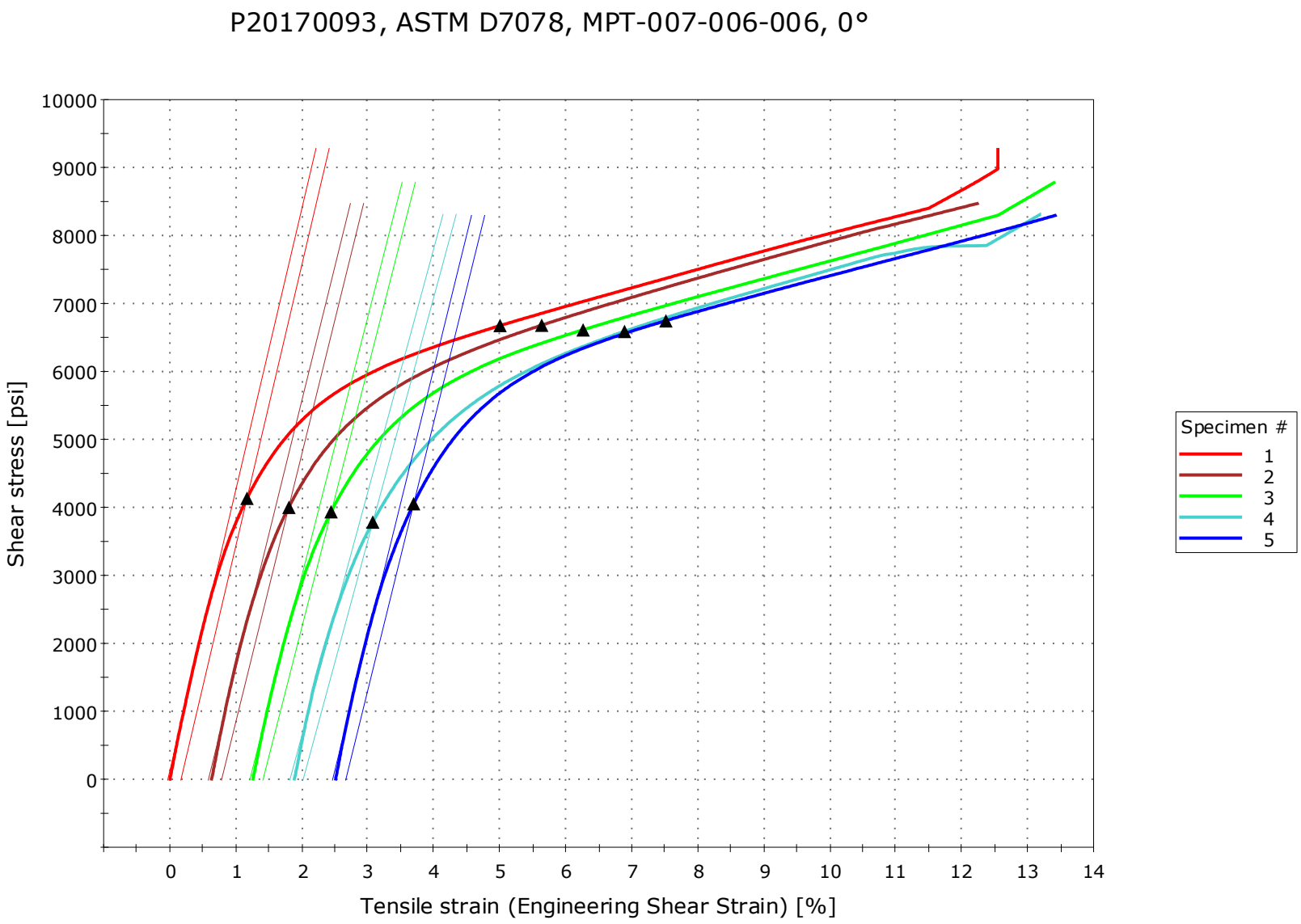

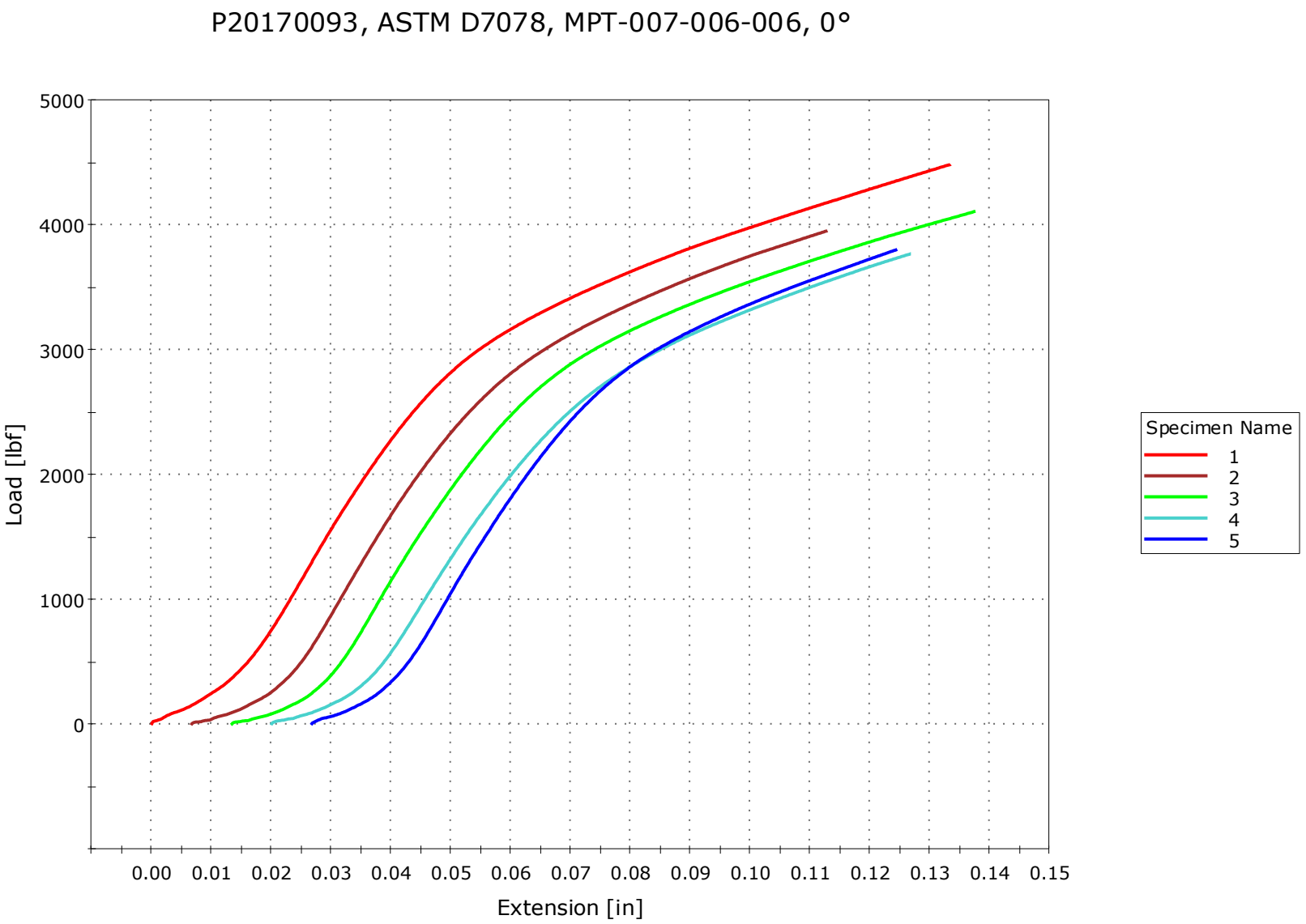

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield — Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady — Attachments : 2 graphs
Date	:	January 23, 2017

Material	:	**MPT-007-006-006**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD438	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.190	0.3868	6790	413000	4180	HGN
2	1.190	0.3812	6570	391000	4100	HGN
3	1.191	0.3814	6510	383000	3930	HGN
4	1.197	0.3769	6540	382000	3930	HGN
5	1.199	0.3791	6530	375000	3980	HGN
		Average	**6590**	**389000**	**4020**	
		Std. Dev.	115	14700	111	
		C.O.V. (%)	2	4	3	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 23, 2017

Material	:	**MPT-007-006-006**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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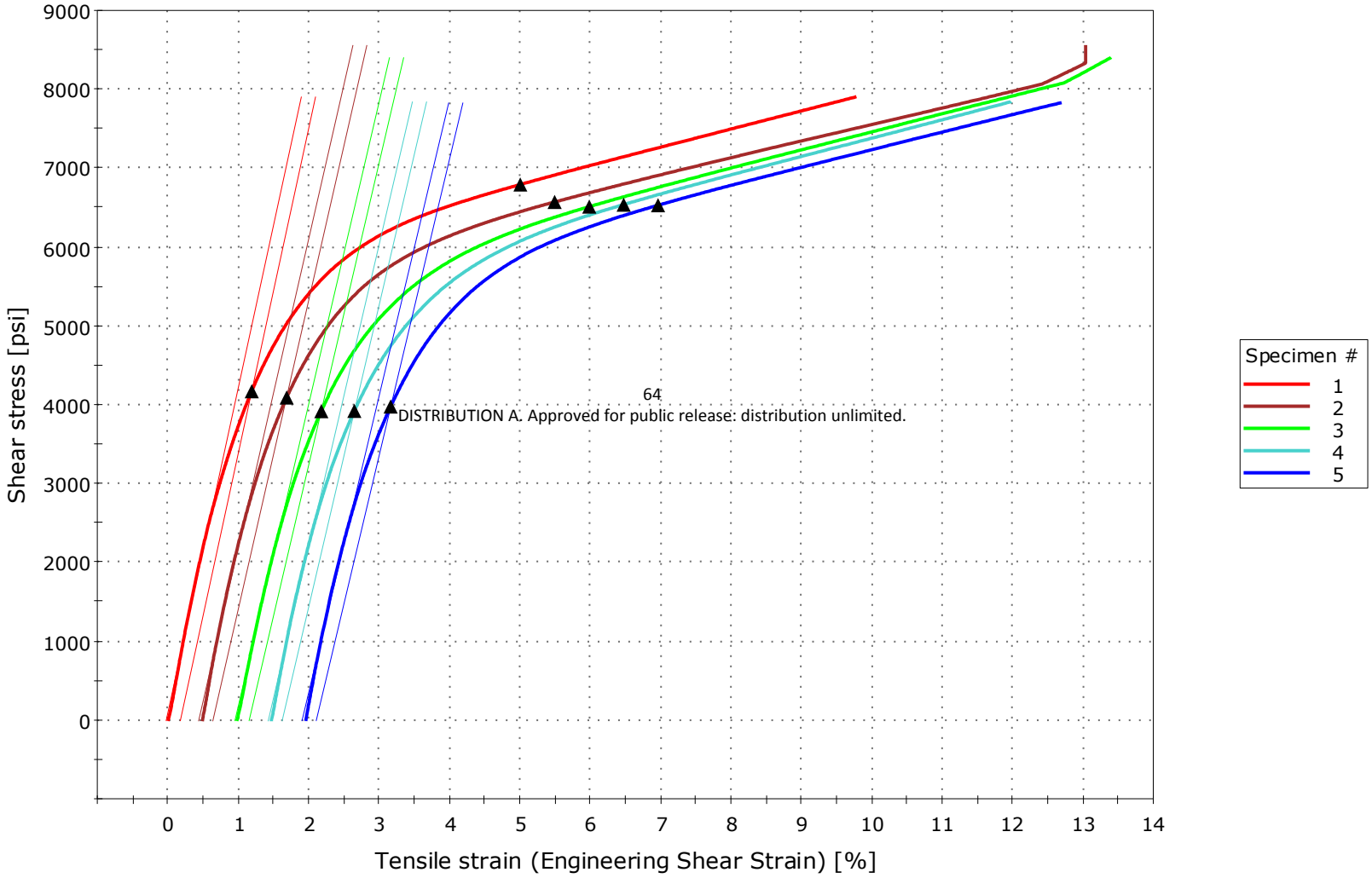
P20170093, ASTM D7078, MPT-007-006-006, 90°



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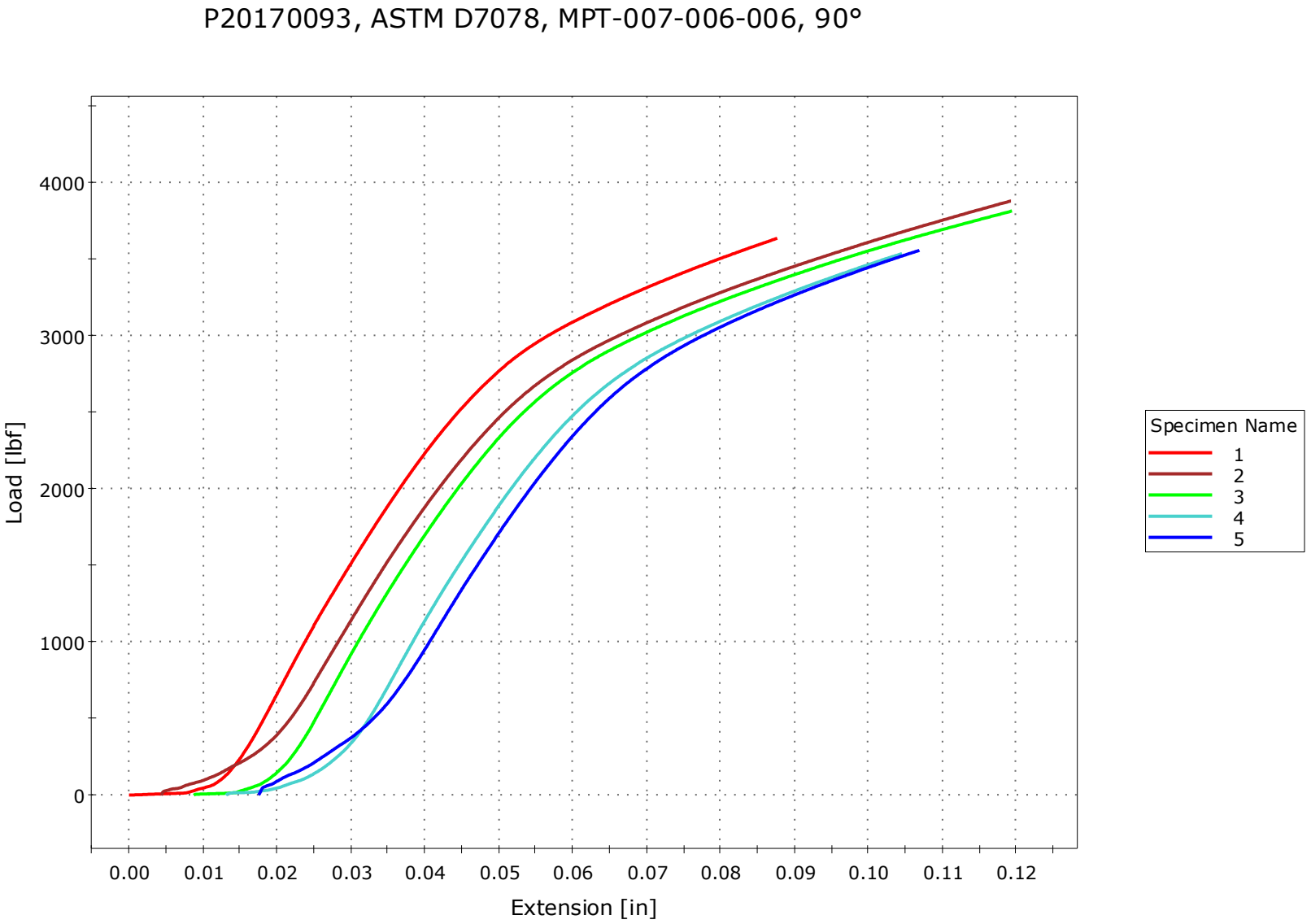

Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 27, 2017	

Material	:	**MPT-007-006-007**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD633	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.201	0.4203	8600	450000	5240	HGN
2	1.201	0.4292	8530	441000	5290	HGN
3	1.200	0.4347	8230	449000	5220	HGN
4	1.203	0.4339	8550	446000	5310	HGN
5	1.199	0.4299	8540	452000	5170	HGN
		Average	**8490**	**448000**	**5250**	
		Std. Dev.	148	4300	56	
		C.O.V. (%)	2	1	1	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 27, 2017

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Material	:	**MPT-007-006-007**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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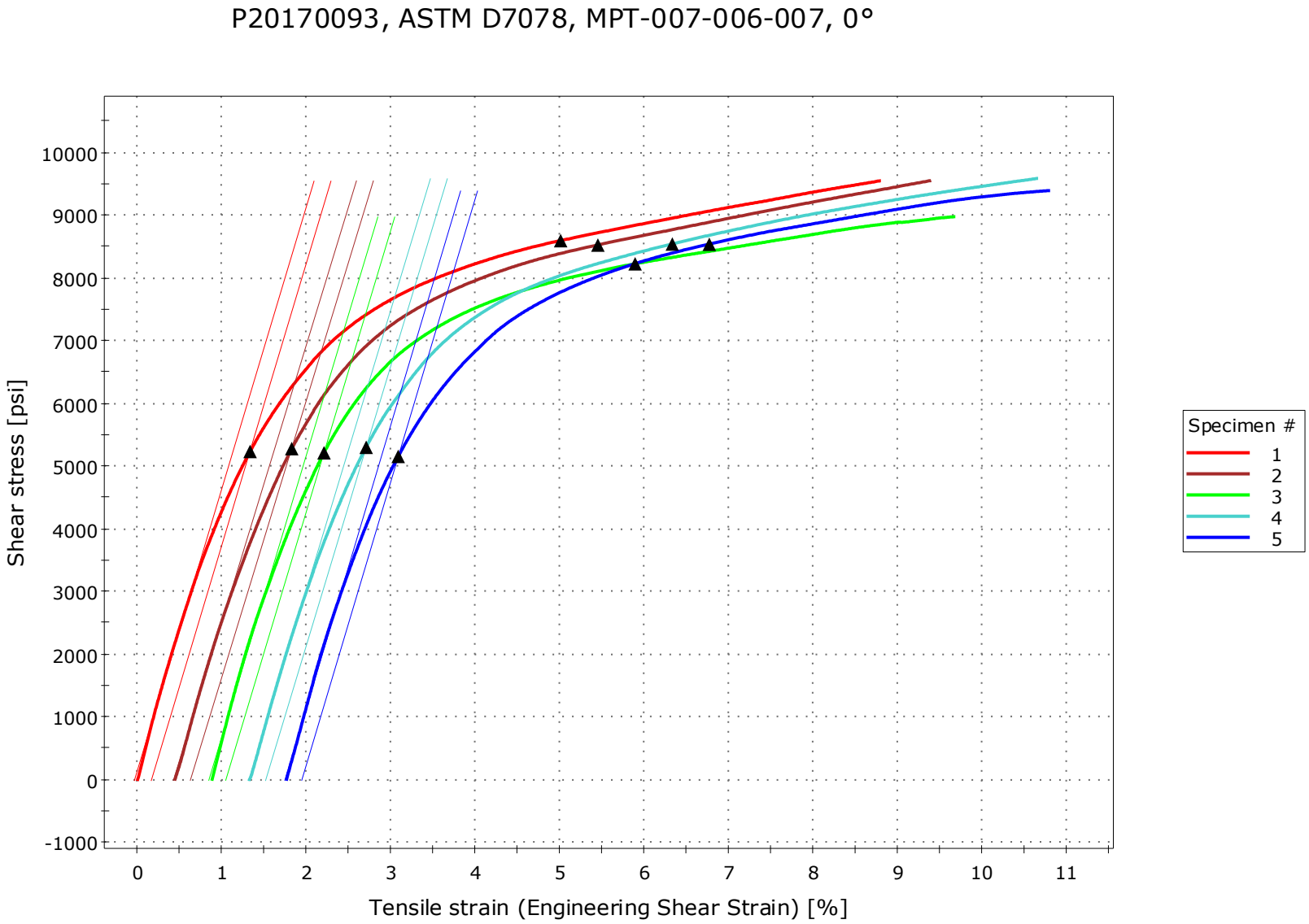

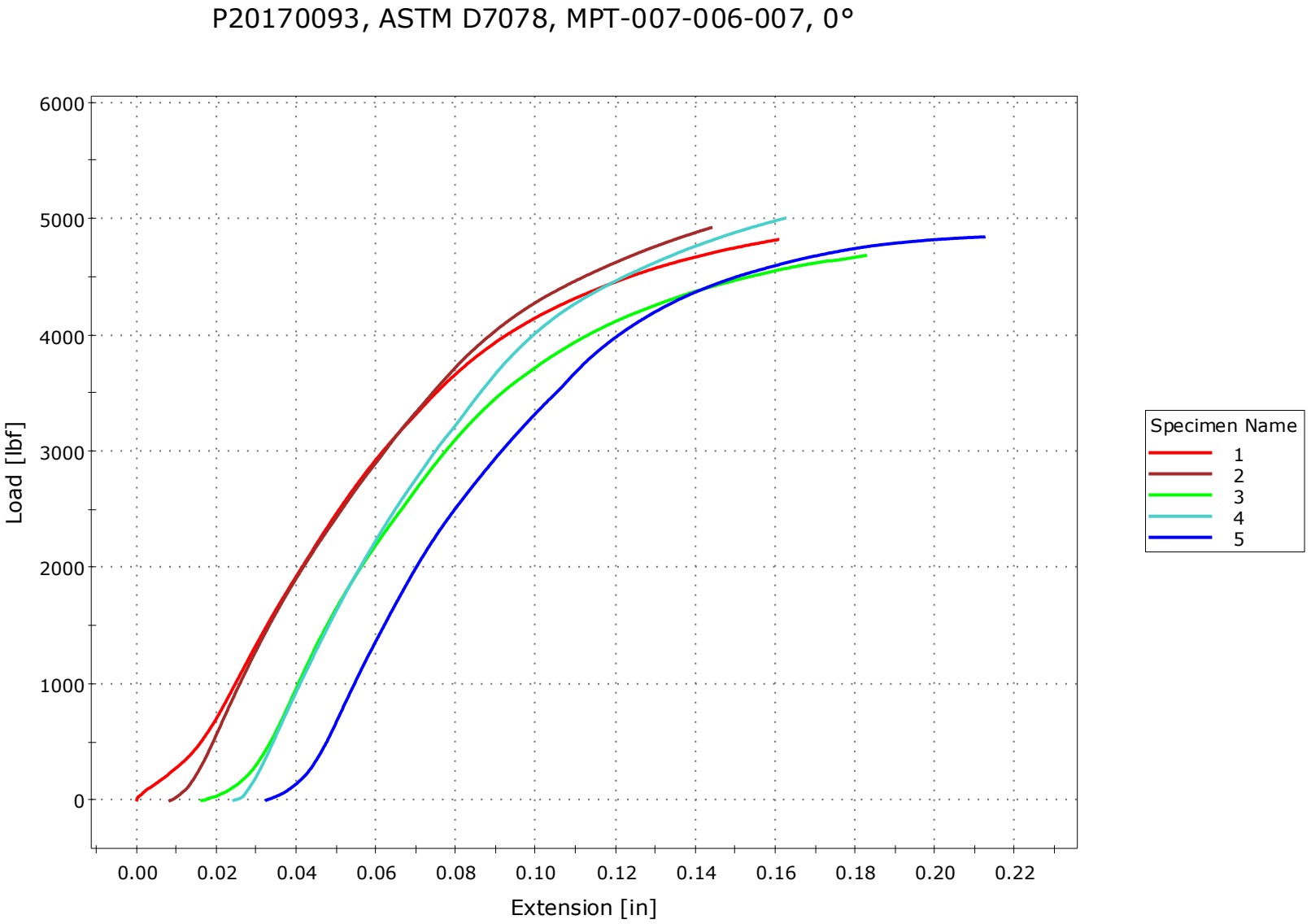

Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 27, 2017	

Material	:	**MPT-007-006-007**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD633	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.204	0.4255	8350	478000	5090	HGN
2	1.194	0.4369	8190	451000	4930	HGN
3	1.207	0.4373	8150	447000	4880	HGN
4	1.198	0.4410	8100	431000	4770	HGN
5	1.192	0.4430	7960	420000	4870	HGN
		Average	**8150**	**445000**	**4910**	
		Std. Dev.	142	22100	117	
		C.O.V. (%)	2	5	2	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 27, 2017

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Material	:	**MPT-007-006-007**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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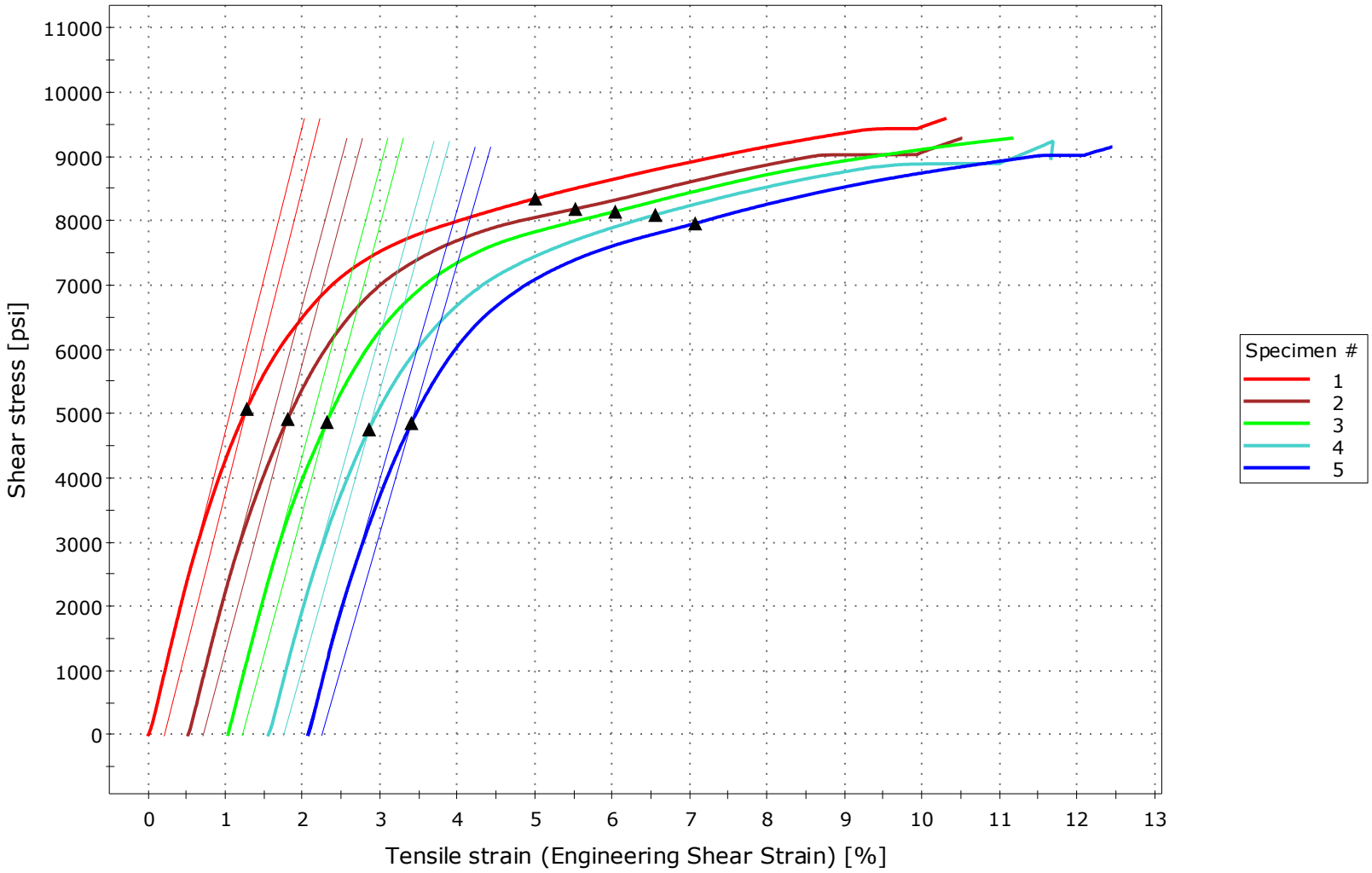
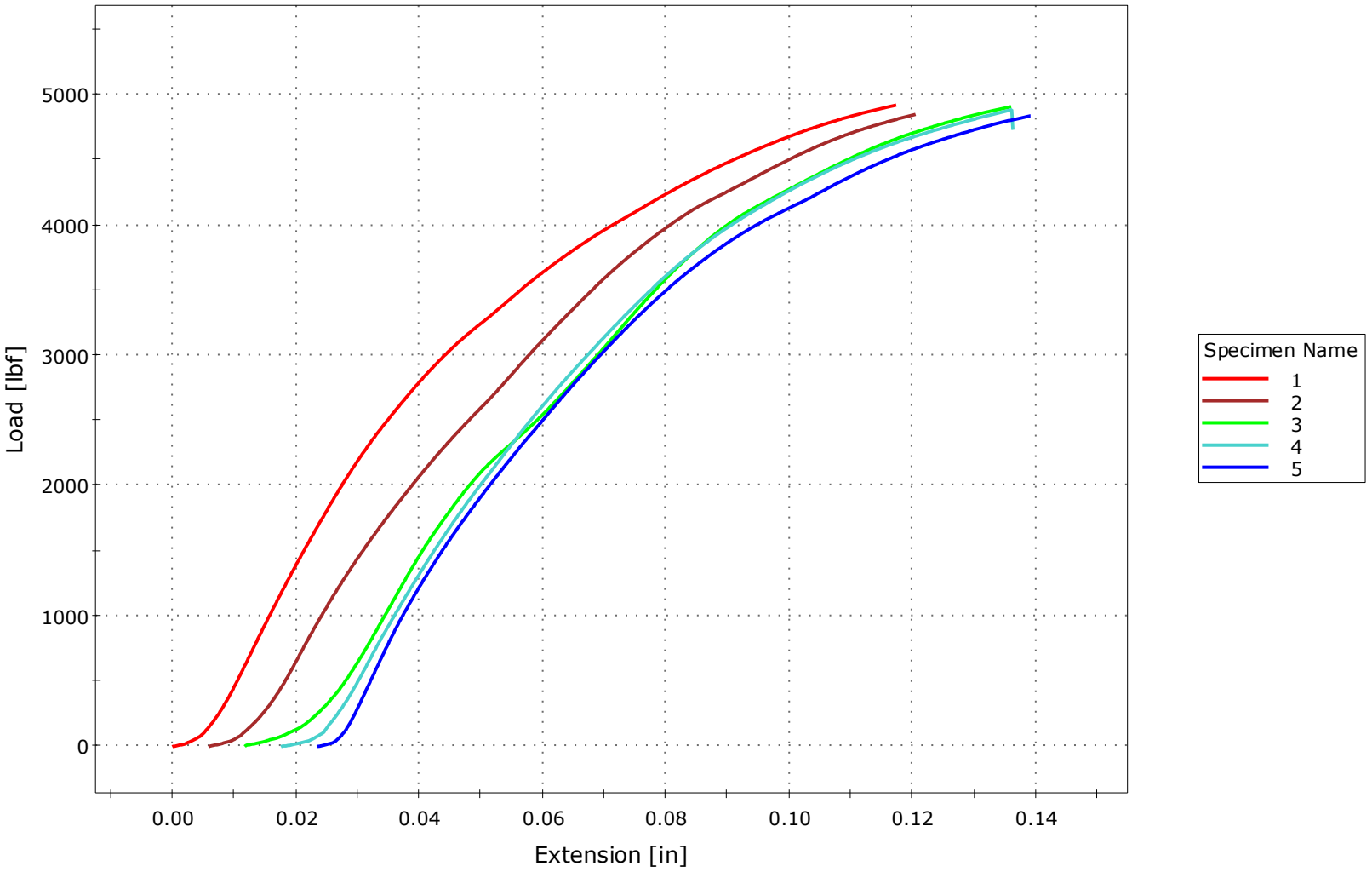
P20170093, ASTM D7078, MPT-007-006-007, 90°



P20170093, ASTM D7078, MPT-007-006-007, 90°



Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 20, 2017	

Material	:	**MPT-007-006-008**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD438	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.210	0.1097	9210	516000	5900	HNV
2	1.212	0.1060	9720	540000	6210	HNV
3	1.210	0.1070	9410	513000	5900	HNV
4	1.209	0.1051	9690	531000	6080	HNV
5	1.208	0.1089	8980	480000	5560	HNV
		Average	**9400**	**516000**	**5930**	
		Std. Dev.	316	22900	245	
		C.O.V. (%)	3	4	4	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 20, 2017

Material	:	**MPT-007-006-008**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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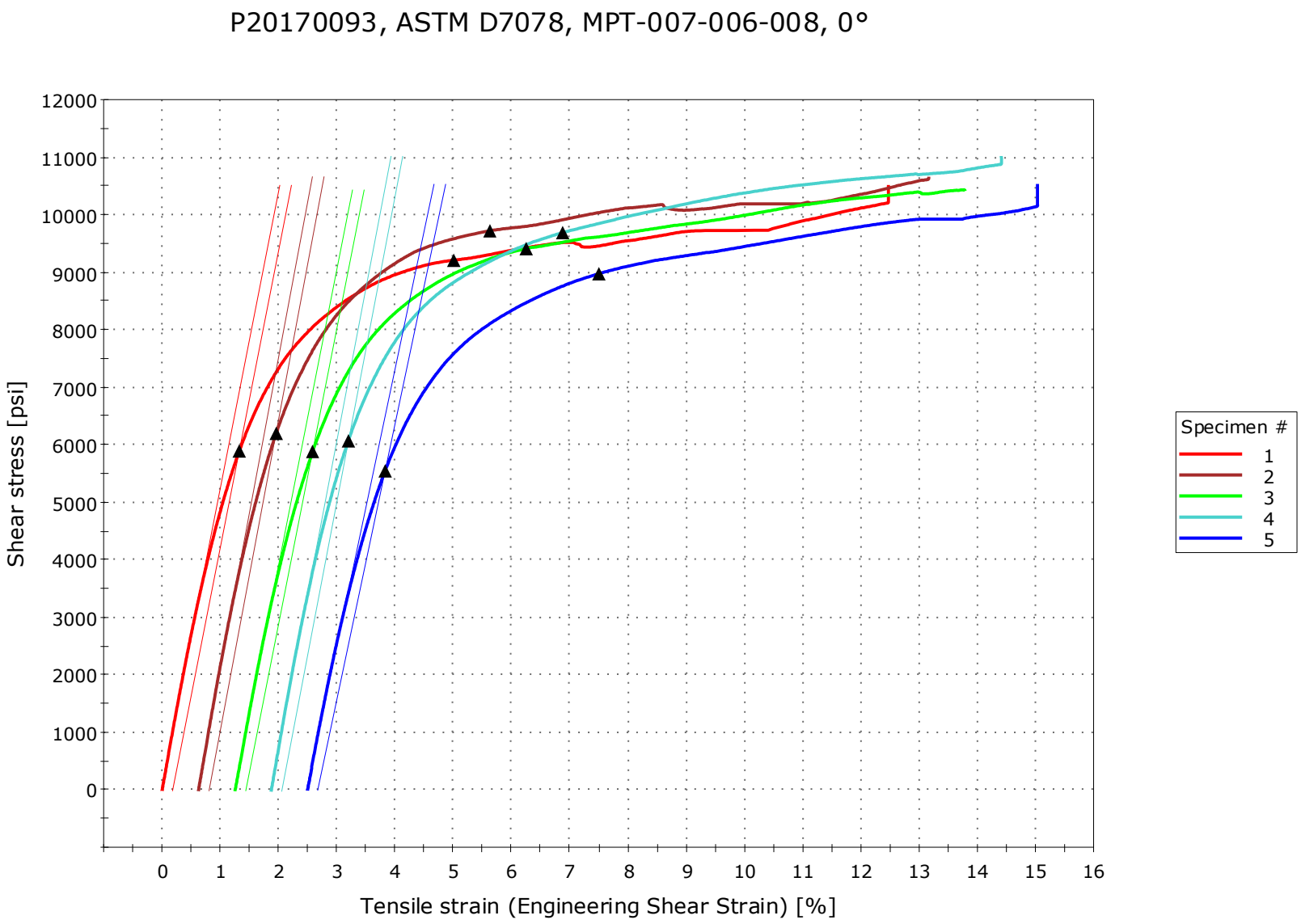

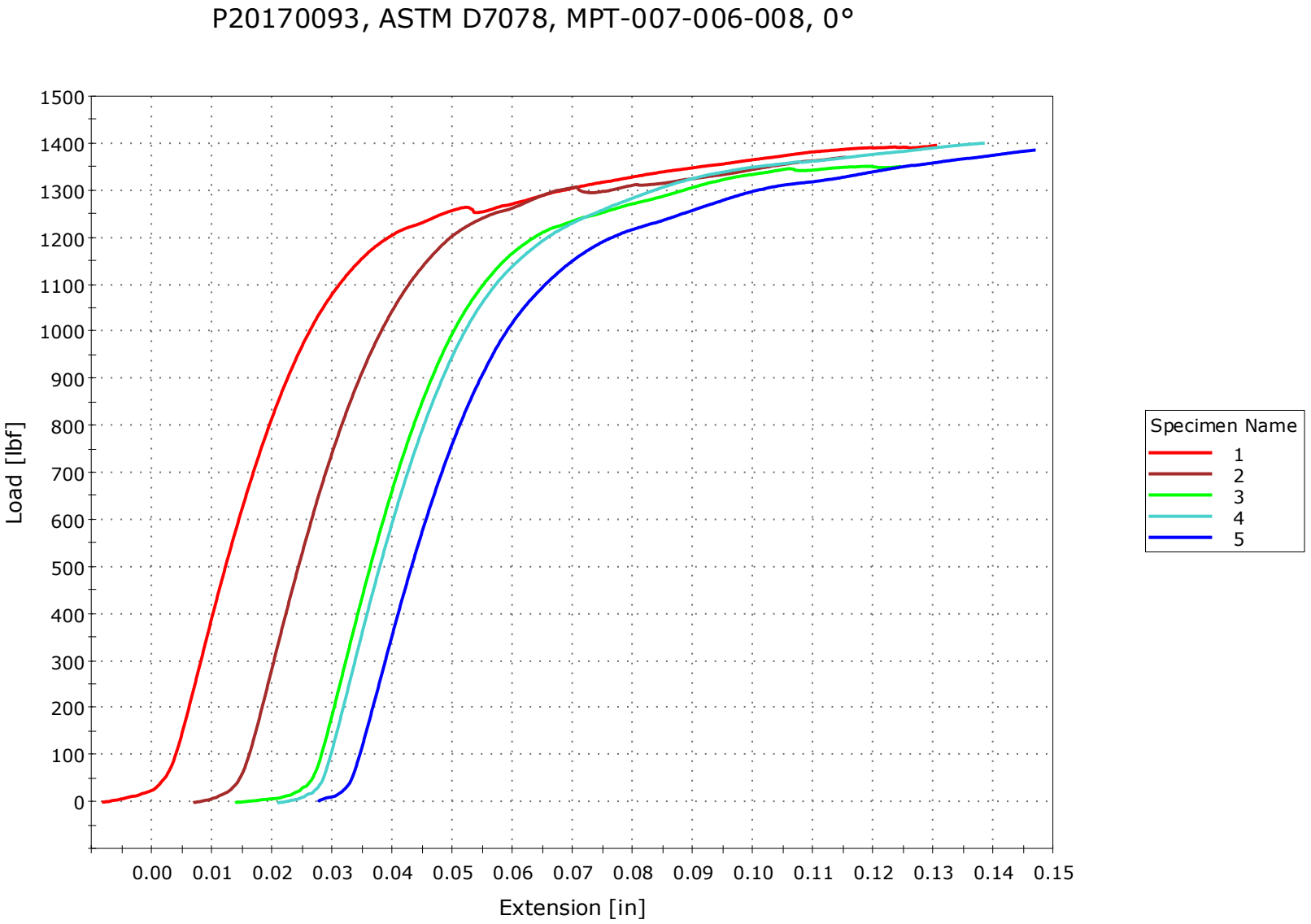

Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**	
Test Method	:	ASTM D7078/D7078M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady	Attachments : 2 graphs
Date	:	January 20, 2017	

Material	:	**MPT-007-006-008**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness (in)	:	Not provided	
Specimen Preparation	:	Machined by Intertek PTL	
Instron Model Number	:	5985	Last Calibration Date : January 2017
Measurement Equipment	:	308, 492	Last Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Last Calibration Date : May 2015
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Cross-Head Speed (in/min)	:	0.05	
Strain Gage Model / Batch No.	:	CEA-06-250UW-350 / A86AD438	
Lead Wire Resistance (Ω, nominal)	:	1	
Significance	:	ASTM D7078 specifies that strength, strain and modulus be reported to three significant figures.	

Test Number	Width (in)	Thickness (in)	Shear Stress at 5% Shear Strain (PSI)	Shear Modulus* (PSI)	0.2% Offset Shear Strength (PSI)	Failure Mode/Location
1	1.207	0.1086	9010	511000	5920	HNV
2	1.207	0.1049	8890	532000	5970	HNV
3	1.206	0.1111	8460	502000	5660	HNV
4	1.209	0.1098	8520	475000	5600	HNV
5	1.207	0.1138	7940	442000	5190	HNV
		Average	**8560**	**492000**	**5670**	
		Std. Dev.	421	34800	311	
		C.O.V. (%)	5	7	5	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Rail Shear Method**
Test Method	:	ASTM D7078/D7078M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield Purchase Order #: 4601885344
Analyst	:	R. Martin / M. Brady
Date	:	January 20, 2017

Material	:	**MPT-007-006-008**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

V-Notched Rail Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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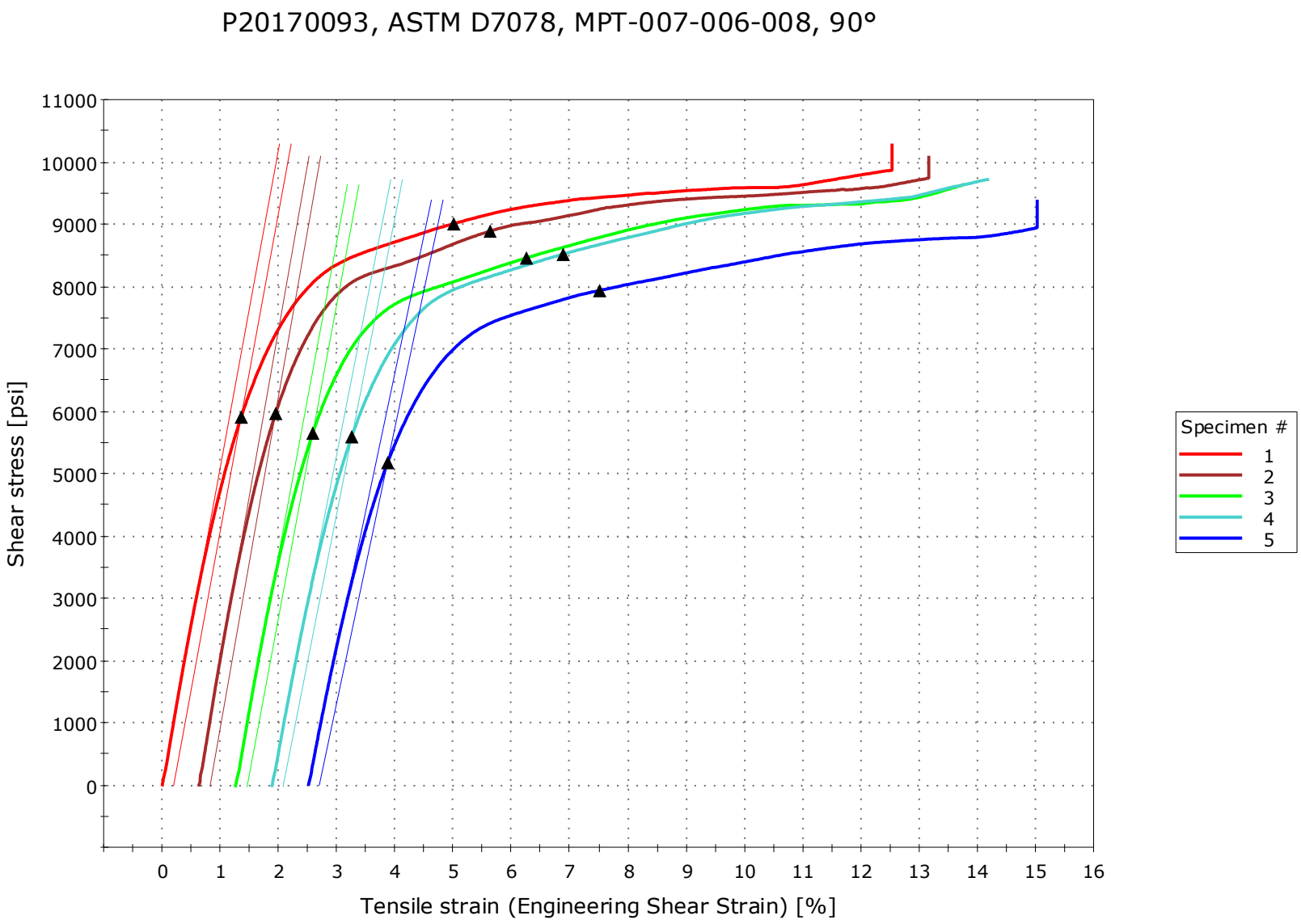
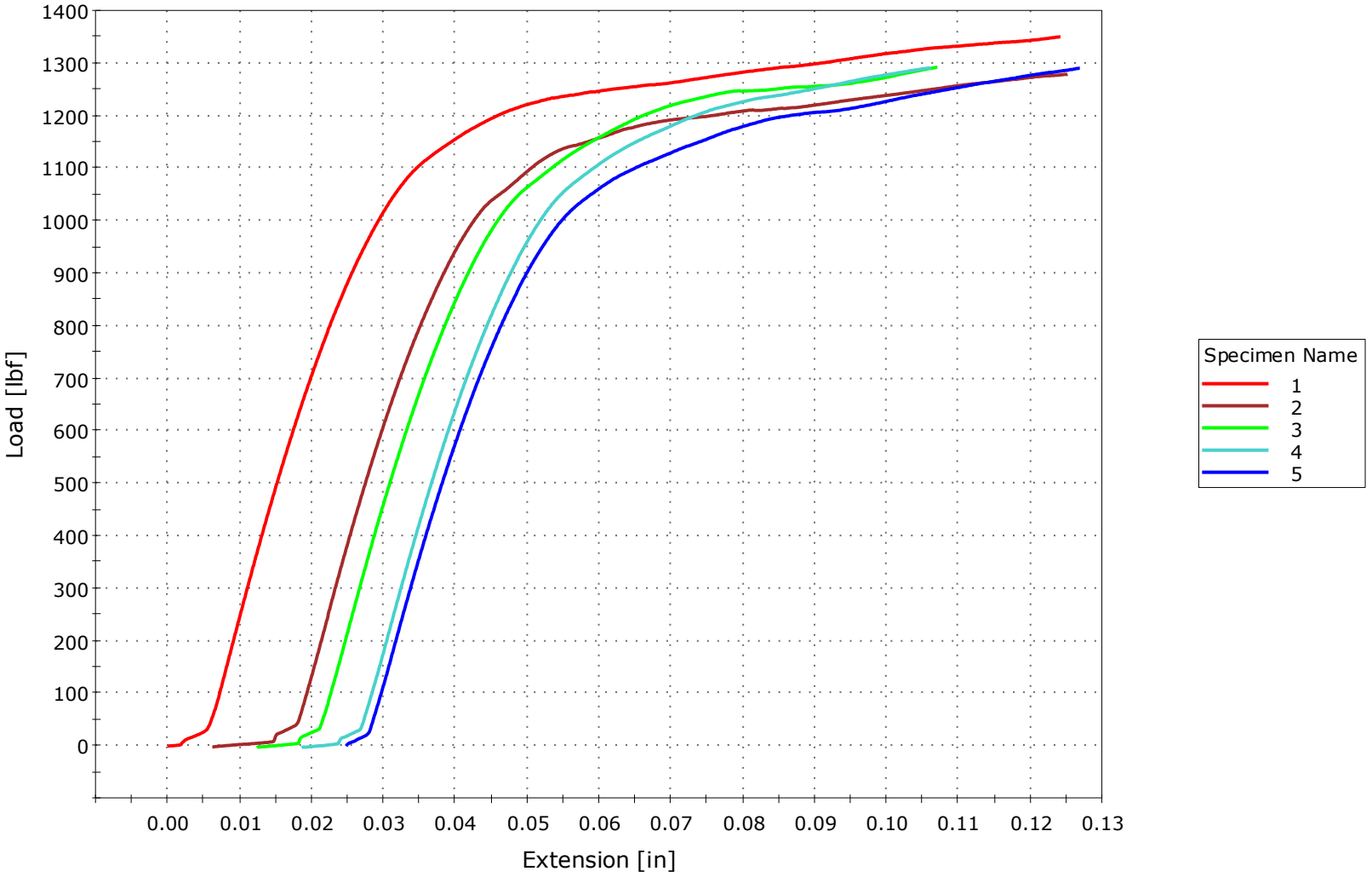


P20170093, ASTM D7078, MPT-007-006-008, 90°



Testing	:	**Shear Properties Of Composite Materials By The V-Notched Beam Method**	
Test Method	:	ASTM D5379/D5379M-12 **Modified number of specimens**	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	Purchase Order #: 4601885344
Attention	:	Andrew Littlefield	Attachments : 2 graphs
Analyst	:	R. Martin / M. Brady	
Date	:	January 24, 2017	

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Material	:	**MPT-007-006-005**	
Ply Orientation / Stacking Sequence	:	**0° / Not provided**	
Average Ply Thickness	:	Not provided	
Measurement Equipment ID	:	308, 492	Calibration Date : January 2017
Strain Gage Model / Batch No.	:	EA-06-125TK-350/E / A86AD992	
Instron Model Number	:	5985	Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Calibration Date : May 2015
Sampling Rate	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D5379 specifies that strength, strain, and modulus be reported to 3 significant figures.	

Test Number	Width (in)	Thickness (in)	**Shear Stress at 5% Shear Strain (PSI)**	**Shear Modulus* (PSI)**	**Failure Codes**
1	0.455	0.3283	7720	449000	HGN
2	0.434	0.3260	7390	351000	HGN
3	0.453	0.3273	7710	518000	HGN
4	0.451	0.3262	7920	500000	HGN
		Average	**7690**	**455000**	
		Std. Dev.	219	74900	
		C.O.V. (%)	3	16	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Beam Method**	
Test Method	:	ASTM D5379/D5379M-12 **Modified number of specimens**	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	Purchase Order #: 4601885344
Attention	:	Andrew Littlefield	Attachments : 2 graphs
Analyst	:	R. Martin / M. Brady	
Date	:	January 24, 2017	

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Material	:	**MPT-007-006-005**
Ply Orientation / Stacking Sequence	:	**0° / Not provided**

V-Notched Beam Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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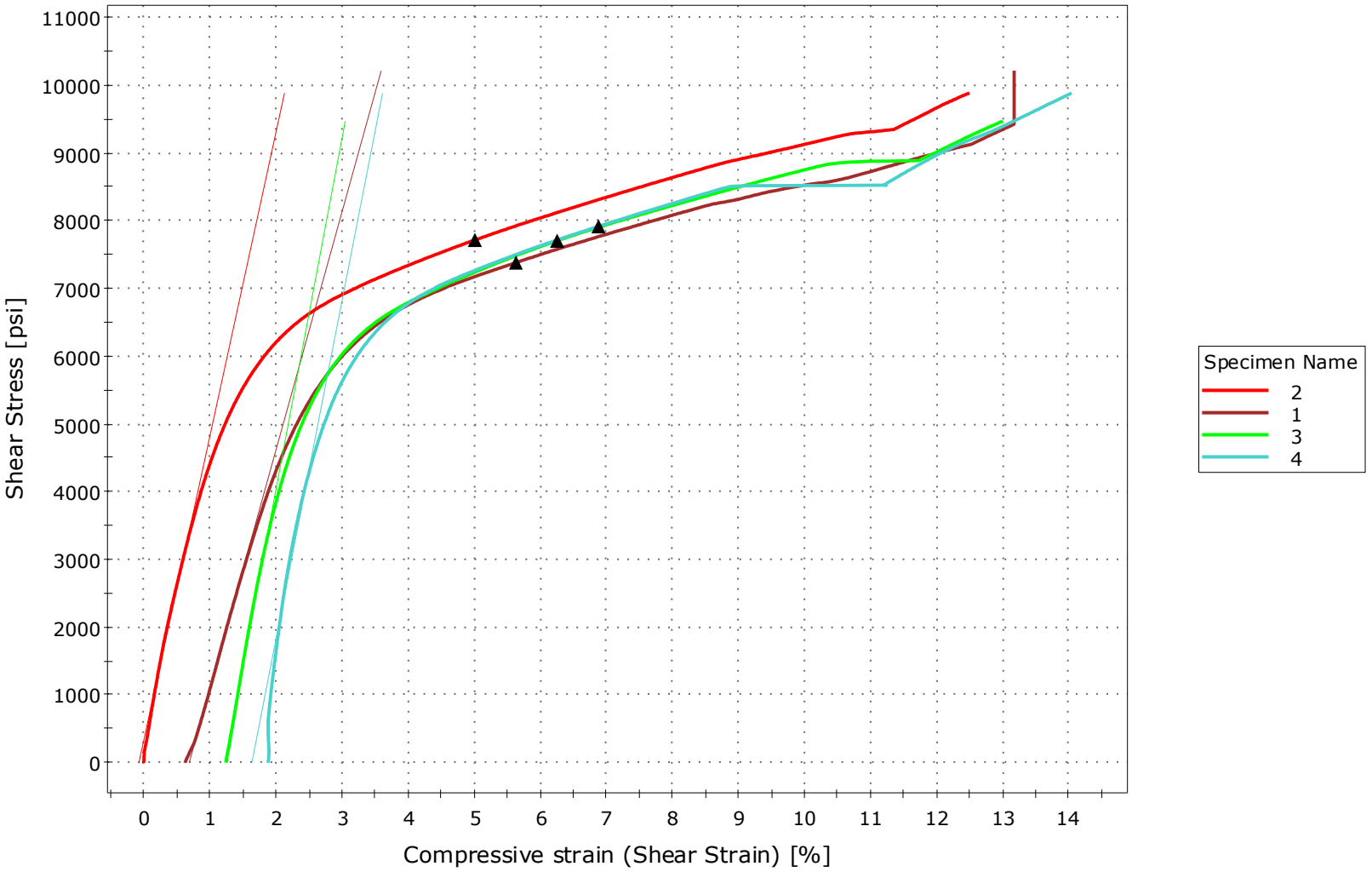
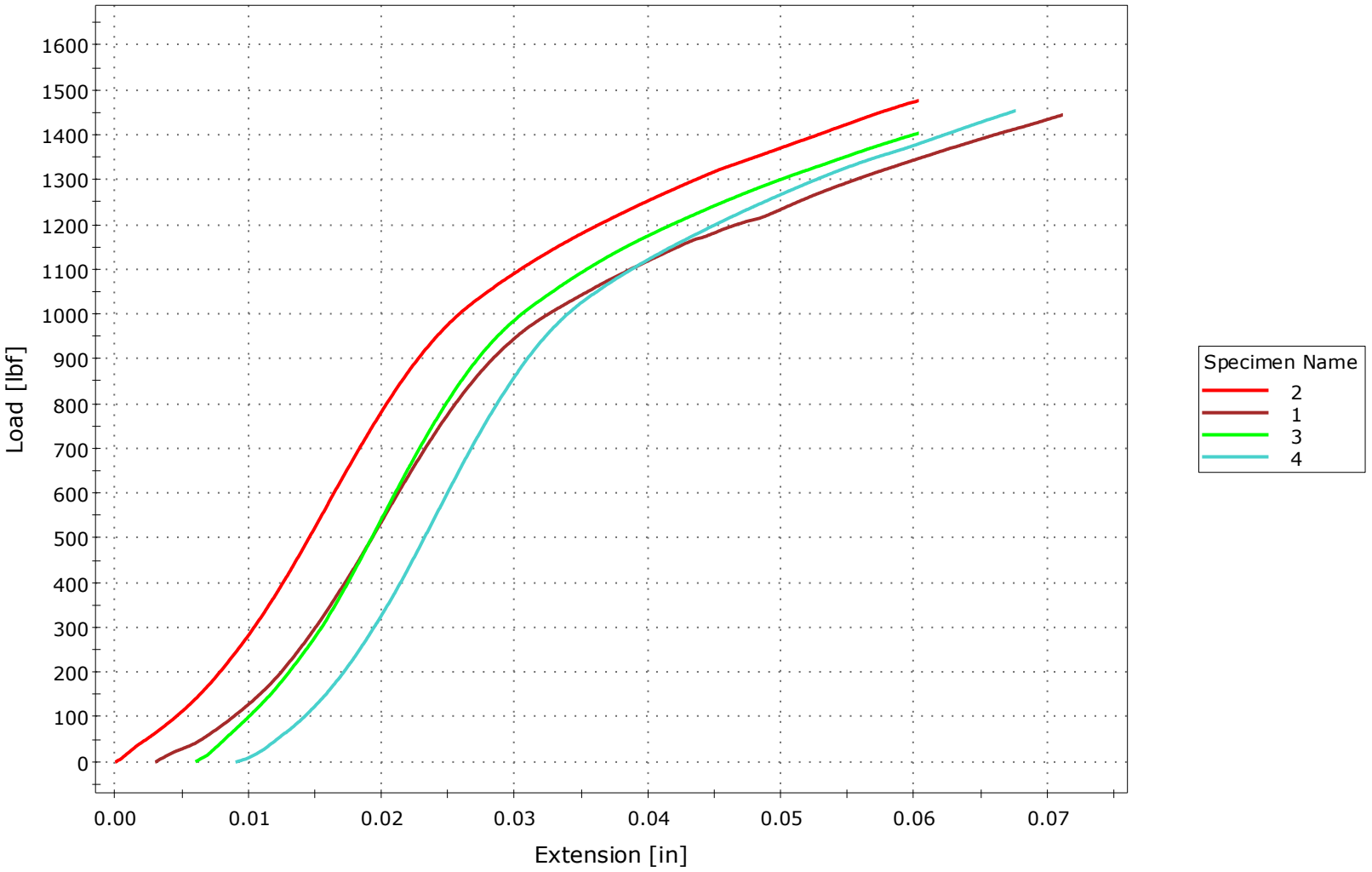
P20170093, ASTM D5379, MPT-007-006-005, 0°



P20170093, ASTM D5379, MPT-007-006-005, 0°



Testing	:	**Shear Properties Of Composite Materials By The V-Notched Beam Method**	
Test Method	:	ASTM D5379/D5379M-12	
Project Number	:	P20170093	
Customer	:	US Army RDECOM-ARDEC Benet Labs	Purchase Order #: 4601885344
Attention	:	Andrew Littlefield	Attachments : 2 graphs
Analyst	:	R. Martin / M. Brady	
Date	:	January 24, 2017	

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Material	:	**MPT-007-006-005**	
Ply Orientation / Stacking Sequence	:	**90° / Not provided**	
Average Ply Thickness	:	Not provided	
Measurement Equipment ID	:	308, 492	Calibration Date : January 2017
Strain Gage Model / Batch No.	:	EA-06-125TK-350/E / A86AD992	
Instron Model Number	:	5985	Calibration Date : January 2017
Data Acquisition	:	Vishay A2 Signal Conditioner	Calibration Date : May 2015
Sampling Rate	:	20	
Cross-Head Speed	:	0.05 in/min	
Conditioning	:	Unconditioned	
Moisture Content	:	Unknown	
Specimen Preparation	:	Machined by Intertek PTL	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D5379 specifies that strength, strain, and modulus be reported to 3 significant figures.	

Test Number	Width (in)	Thickness (in)	**Shear Stress at 5% Shear Strain (PSI)**	**Shear Modulus* (PSI)**	**Failure Codes**
1	0.452	0.3372	7570	526000	HGN
2	0.448	0.3258	7690	497000	HGN
3	0.448	0.3205	7730	511000	HGN
4	0.453	0.3277	7650	529000	HGN
5	0.451	0.3370	7430	506000	HGN
		Average	**7610**	**514000**	
		Std. Dev.	119	13500	
		C.O.V. (%)	2	3	

* : Chord modulus taken from 0.2% to 0.6%

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Testing	:	**Shear Properties Of Composite Materials By The V-Notched Beam Method**
Test Method	:	ASTM D5379/D5379M-12
Project Number	:	P20170093
Customer	:	US Army RDECOM-ARDEC Benet Labs
Attention	:	Andrew Littlefield
Analyst	:	R. Martin / M. Brady
Date	:	January 24, 2017

Purchase Order #: 4601885344
Attachments : 2 graphs

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Material	:	**MPT-007-006-005**
Ply Orientation / Stacking Sequence	:	**90° / Not provided**

V-Notched Beam Shear Test Failure Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Location	Code
Horizontal Cracking	H	Gage section	G	Bottom	B
Vertical Cracking	V	Notch region	N	Top	T
Angled Cracking	A	Side region	S	Left	L
Edge Crushing	E	Multiple areas	M	Right	R
Multi-mode	M(xyz)	Various	V	Between Notches	N
Other	O	Unknown	U	Adjacent to Notches	A
				Top and/or bottom edge	E
				Various	V
				Unknown	U

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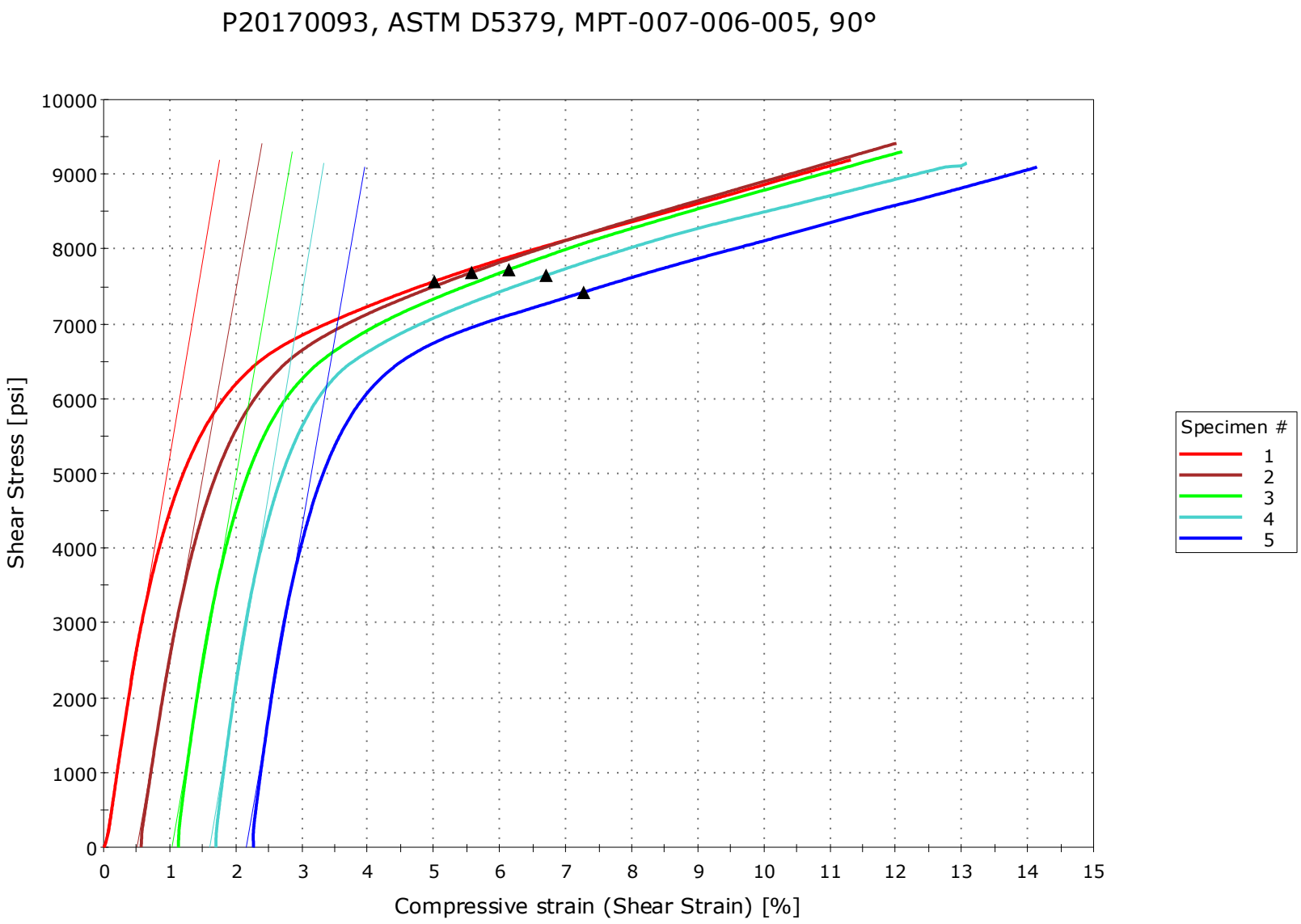

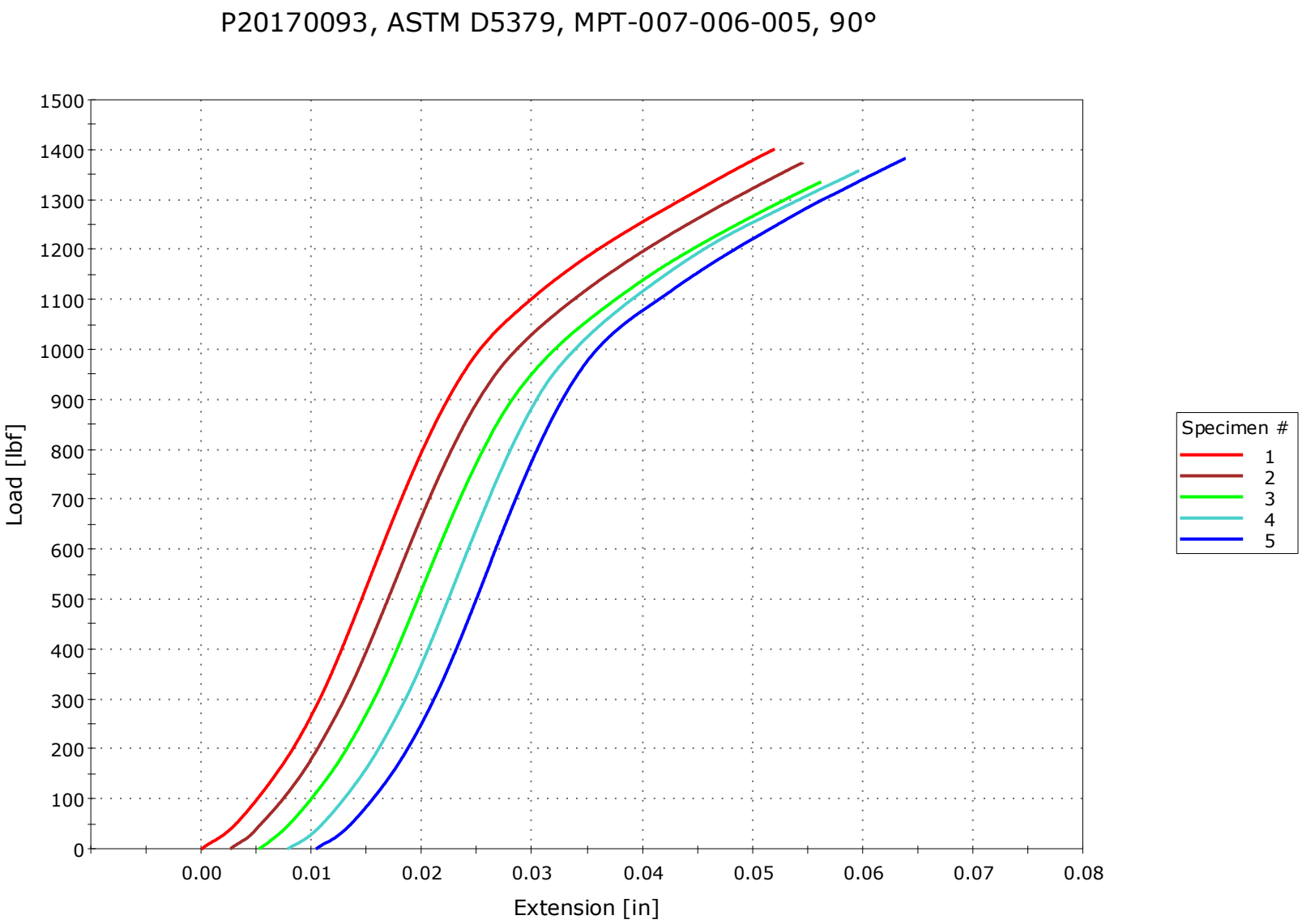

Testing	:	**Through-Thickness "Flatwise" Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material**	
Test Method	:	ASTM D7291/D7291M-15	
Project Number	:	P20170093	Purchase Order: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M.Brady / K. Schuman	Attachments: 2 Graphs
Date	:	February 6, 2017	

Material / Sample Name	:	**MPT-007-006-006**
Ply Orientation / Stacking Sequence	:	Not provided
Average Ply Thickness	:	Not provided
Sample Preparation	:	Machined by Intertek PTL using a diamond grit wet saw. Post-bond machining performed by an approved outside source
Sample Bonding	:	Bonded to loading fixtures using Cybercryl 800
Tab Dimensions	:	1.0" diameter
Tab Material	:	Steel
Instron Model Number	:	5985 Calibration Date : January 2017
Measurement Equipment	:	509, 306 Calibration Date : January 2017
Strain Gage Model Number	:	HBM 1-LY71-3/350
Strain Gage Orientation	:	180°
Alignment Results	:	Self-aligning grips used.
Cross-Head Speed (in/min)	:	0.005
Sampling Rate (data points/s)	:	20
Conditioning	:	Unconditioned
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH

Test Number	Sample Diameter (in)	Maximum Load Achieved (lbs)	Max Flatwise Tensile Stress (PSI)	Flatwise Tensile Modulus 0.027% - 0.055% (PSI)	Failure Mode
1	1.000	1810	2300	1950000	SA (Cohesive)
2	0.999	1980	2530	1940000	SA (Cohesive)
3	0.999	2020	2570	2040000	SA (Cohesive)
4	0.999	1980	2530	2100000	SA (Cohesive)
5	1.001	1890	2400	2070000	SA (Cohesive)
Average		**1940**	**2470**	**2020000**	
Std Dev		85	113	71764	
C.O.V. (%)		4	5	4	

Failure Mode

SG - along a single plane within the gage section of the specimen
MG - along multiple planes within the gage section of the specimen
SA - partly through the specimen surface ply or plies and partly through the adhesive
AB - adhesive failure along bond line

Note: The (SA) and (AB) failure modes are not acceptable failure modes and the strength data shall be noted as invalid.

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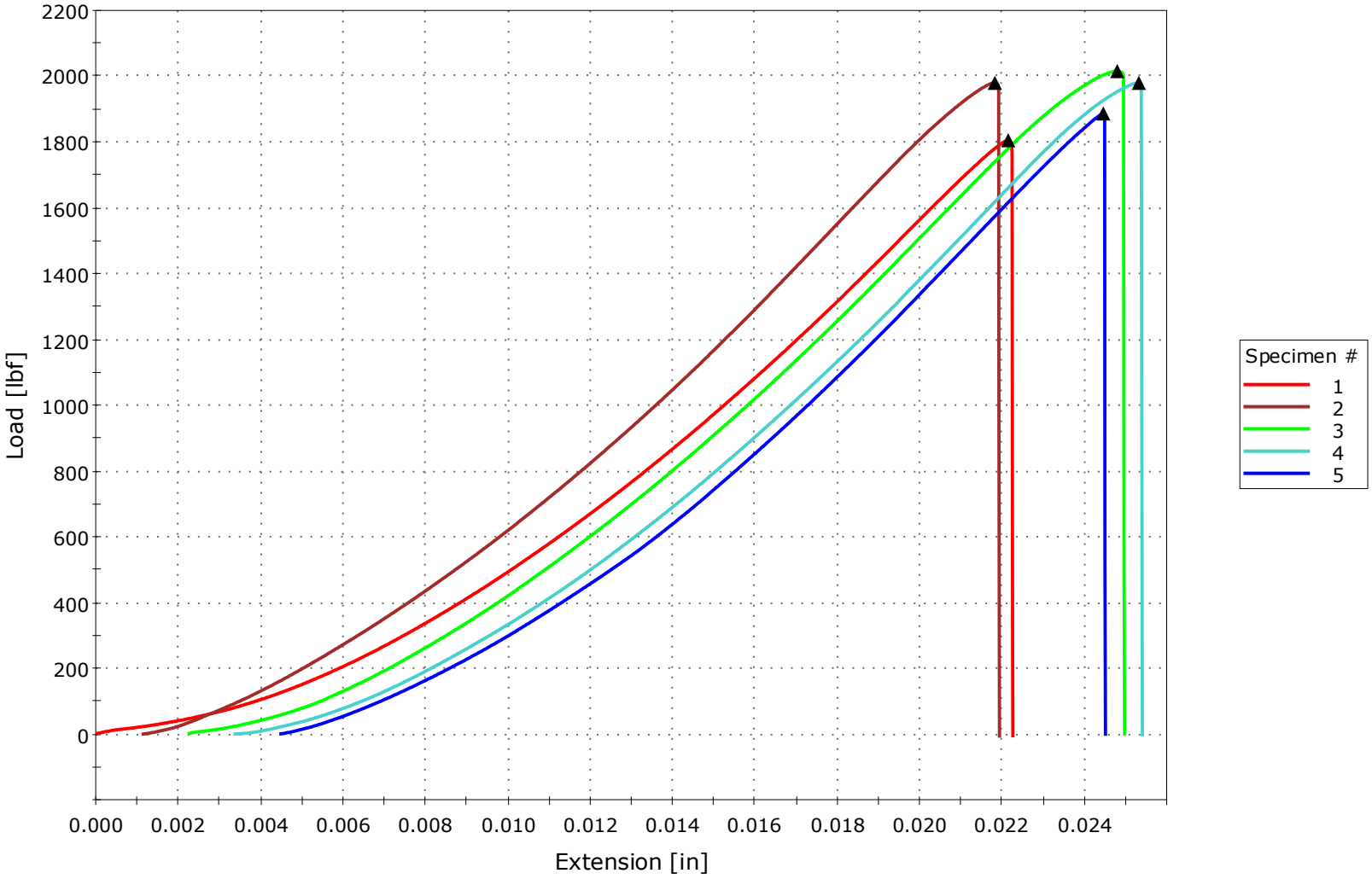
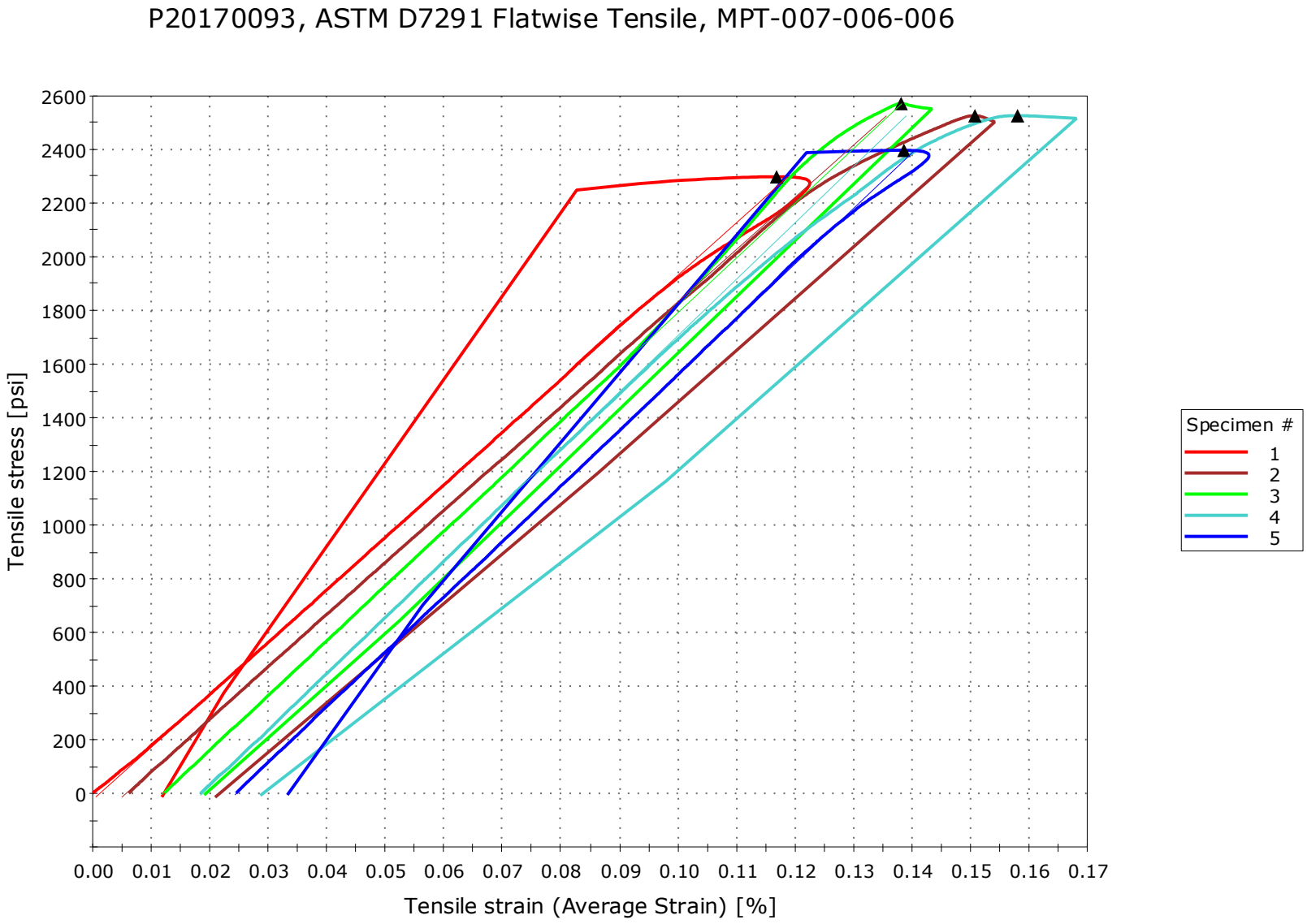
P20170093, ASTM D7291 Flatwise Tensile, MPT-007-006-006





Testing	:	**Through-Thickness "Flatwise" Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material**	
Test Method	:	ASTM D7291/D7291M-15	
Project Number	:	P20170093	Purchase Order: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	R. Martin / M.Brady	Attachments: 2 Graphs
Date	:	February 10, 2017	

Material / Sample Name	:	**MPT-007-006-001**
Ply Orientation / Stacking Sequence	:	Not provided
Average Ply Thickness	:	Not provided
Sample Preparation	:	Machined by Intertek PTL using a diamond grit wet saw. Post-bond machining performed by an approved outside source
Sample Bonding	:	Bonded to loading fixtures using Cybercryl 800
Tab Dimensions	:	1.0" diameter
Tab Material	:	Steel
Instron Model Number	:	5985 Calibration Date : January 2017
Measurement Equipment	:	509, 308 Calibration Date : January 2017
Strain Gage Model Number	:	HBM 1-LY71-3/350
Strain Gage Orientation	:	180°
Alignment Results	:	Self-aligning grips used.
Cross-Head Speed (in/min)	:	0.005
Sampling Rate (data points/s)	:	20
Conditioning	:	Unconditioned
Test Conditions	:	23℃ ± 2℃ / 50% ± 10% RH
Significance	:	ASTM D7291 specifies that stress and modulus be reported to 3 significant figures.

Test Number	Sample Diameter (in)	Maximum Load Achieved (lbs)	Max Flatwise Tensile Stress (PSI)	Flatwise Tensile Modulus 0.040% - 0.080% (PSI)	Failure Mode
1	0.999	2020	2570	1840000	SA (Cohesive)
2	1.001	2090	2660	2040000	SA (Cohesive)
3	1.000	2200	2800	2000000	SA (Cohesive)
4	1.001	2140	2720	2000000	SA (Cohesive)
5	0.999	2260	2880	2000000	SA (Cohesive)
	Average	**2140**	**2730**	**1980000**	
	Std Dev	93	120	78000	
	C.O.V. (%)	4	4	4	

Failure Mode

SG - along a single plane within the gage section of the specimen
MG - along multiple planes within the gage section of the specimen
SA - partly through the specimen surface ply or plies and partly through the adhesive
AB - adhesive failure along bond line

Note: The (SA) and (AB) failure modes are not acceptable failure modes and the strength data shall be noted as invalid.

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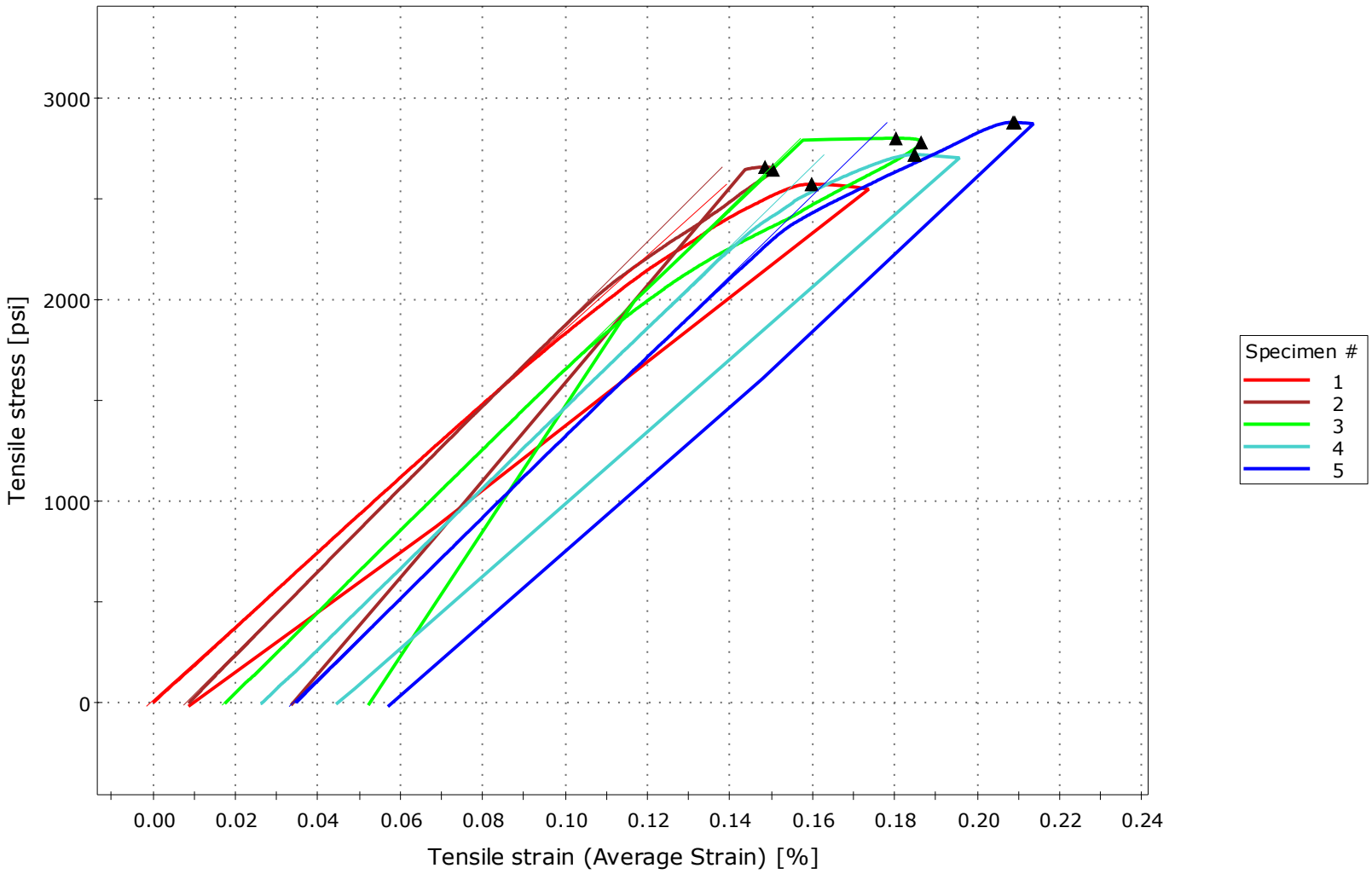
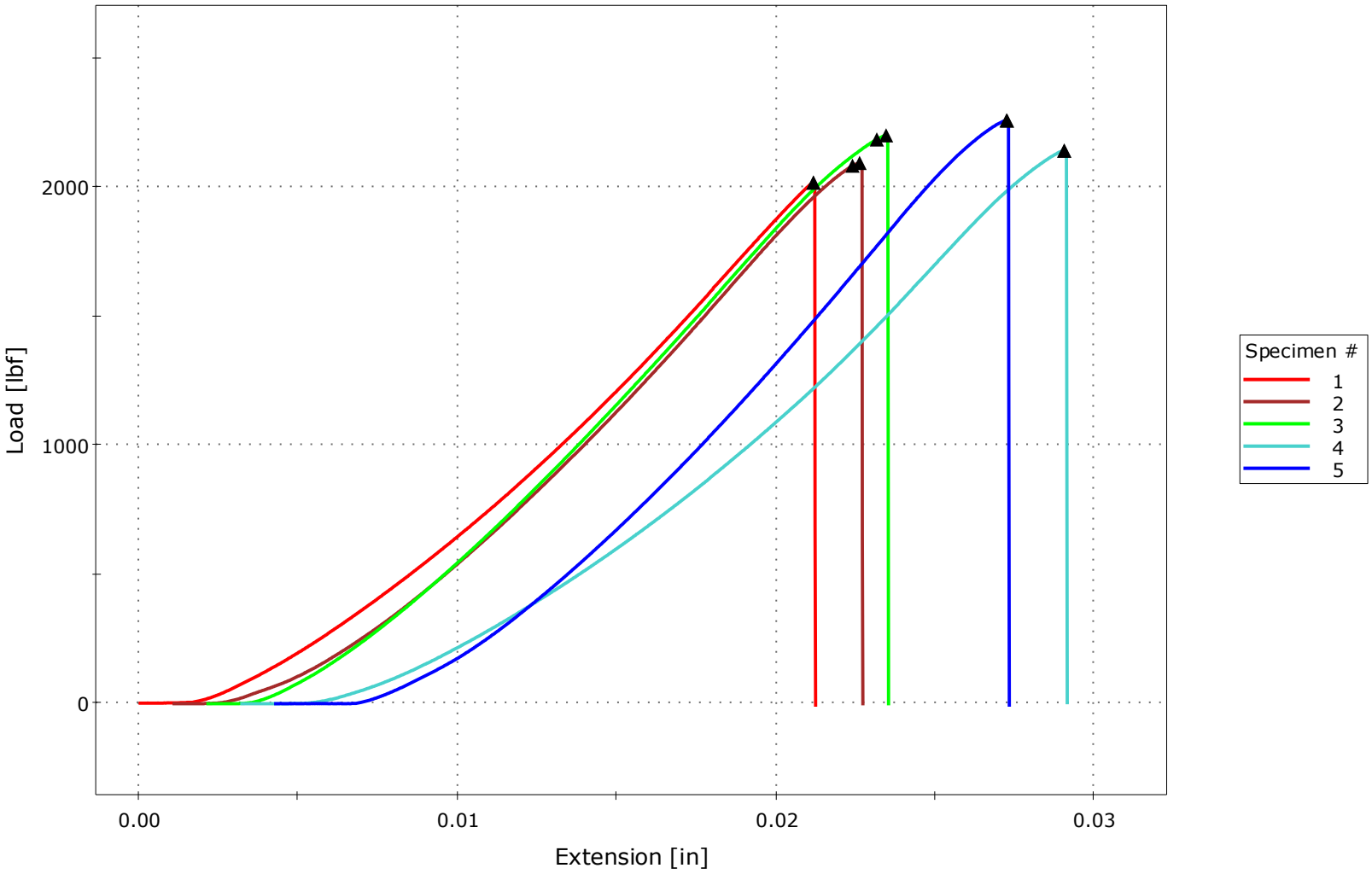


P20170093, ASTM D7291 Flatwise Tensile, MPT-007-006-001



Testing	:	**Through-Thickness "Flatwise" Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material**	
Test Method	:	ASTM D7291/D7291M-15	
Project Number	:	P20170093	Purchase Order: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M.Brady / K. Schuman	Attachments: 2 Graphs
Date	:	February 21, 2017	

Material / Sample Name	:	**MPT-007-006-004**	
Ply Orientation / Stacking Sequence	:	Not provided	
Average Ply Thickness	:	Not provided	
Fabrication Process	:	Unknown (prepared by customer)	
Sample Preparation	:	Machined by Intertek PTL using a diamond grit wet saw. Post-bond machining performed by an approved outside source	
Sample Bonding	:	Bonded to loading fixtures using Cybercryl 800	
Tab Dimensions	:	1.0" diameter	
Tab Material	:	Steel	
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308, 648	Calibration Date : January 2017, November 2016
Strain Gage Model Number	:	HBM 1-LY71-3/350	
Strain Gage Orientation	:	180°	
Alignment Results	:	Self-aligning grips used.	
Cross-Head Speed (in/min)	:	0.005	
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D7291 specifies that stress and modulus be reported to 3 significant figures.	

Test Number	Sample Diameter (in)	Maximum Load Achieved (lbs)	Max Flatwise Tensile Stress (PSI)	Flatwise Tensile Modulus 0.048% - 0.095% (PSI)	Failure Mode
1	0.997	2300	2950	1790000	SA (Cohesive)
2	1.001	2360	3000	1980000	SA (Cohesive)
3	0.999	2190	2800	1680000	SA (Cohesive)
4	0.997	2220	2850	1560000	SA (Cohesive)
5	1.000	2300	2930	1760000	SA (Cohesive)
	Average	**2270**	**2910**	**1750000**	
	Std Dev	68	80	155000	
	C.O.V. (%)	3	3	9	

Failure Mode

SG - along a single plane within the gage section of the specimen
MG - along multiple planes within the gage section of the specimen
SA - partly through the specimen surface ply or plies and partly through the adhesive
AB - adhesive failure along bond line

Note: The (SA) and (AB) failure modes are not acceptable failure modes and the strength data shall be noted as invalid.

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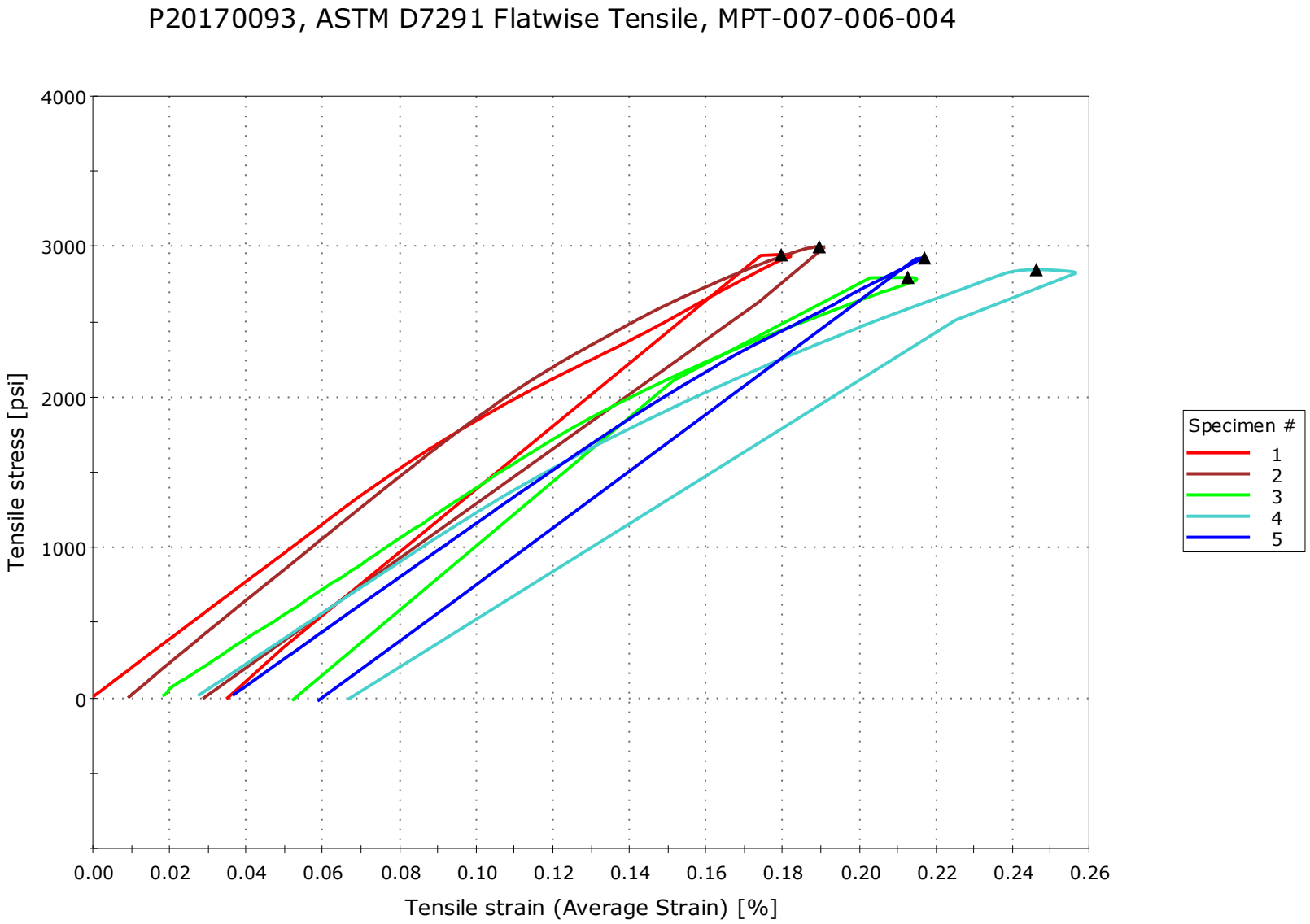
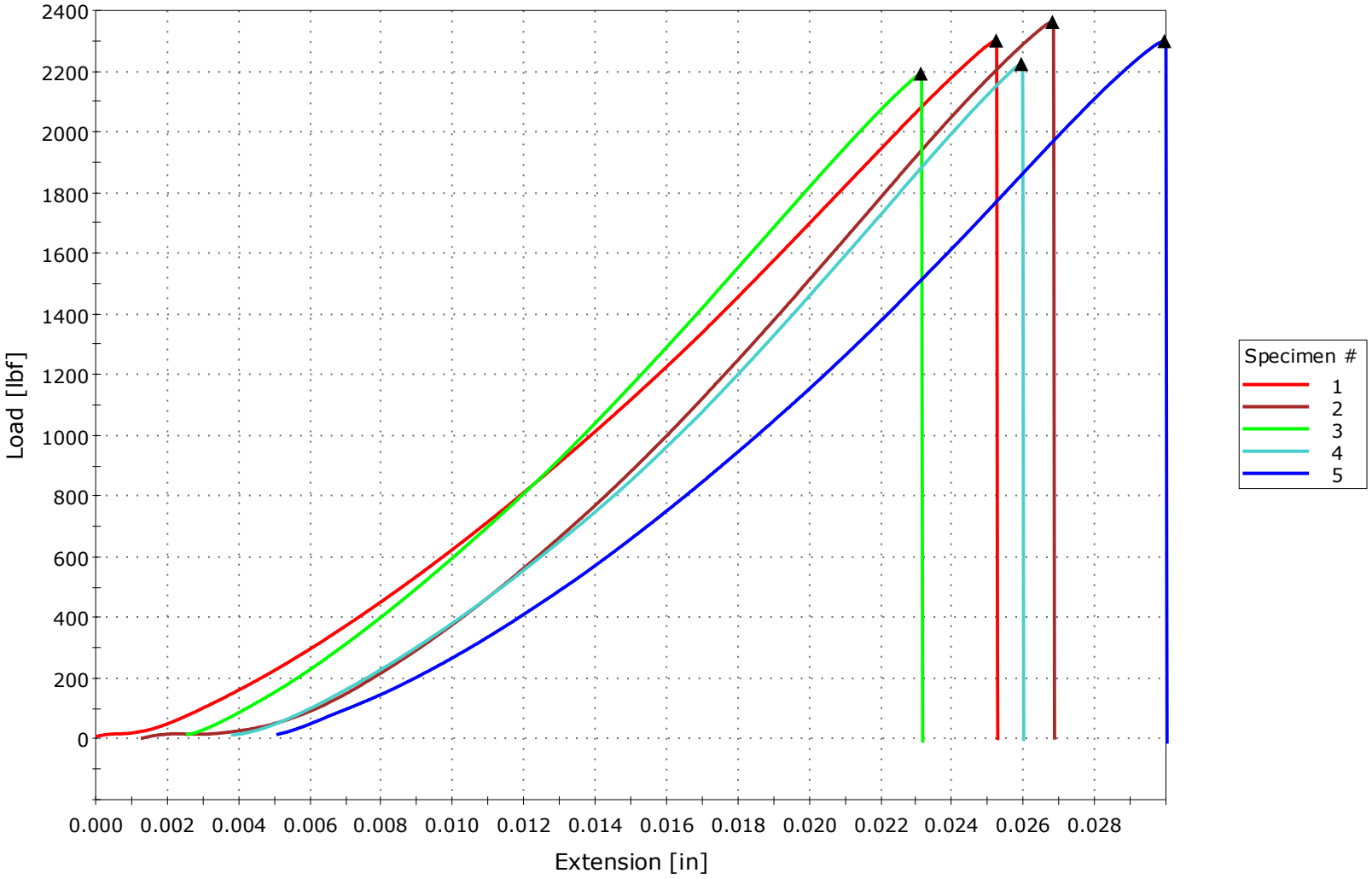


P20170093, ASTM D7291 Flatwise Tensile, MPT-007-006-004



Testing	:	**Through-Thickness "Flatwise" Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material**	
Test Method	:	ASTM D7291/D7291M-15	
Project Number	:	P20170093	Purchase Order: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M.Brady	Attachments: 2 Graphs
Date	:	February 23, 2017	

Material / Sample Name	:	**MPT-007-006-005**	
Ply Orientation / Stacking Sequence	:	Not provided	
Average Ply Thickness	:	Not provided	
Fabrication Process	:	Unknown (prepared by customer)	
Sample Preparation	:	Machined by Intertek PTL using a diamond grit wet saw. Post-bond machining performed by an approved outside source	
Sample Bonding	:	Bonded to loading fixtures using Cybercryl 800	
Tab Dimensions	:	1.0" diameter	
Tab Material	:	Steel	
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	308, 618	Calibration Date : January 2017
Strain Gage Model Number	:	HBM 1-LY71-3/350	
Strain Gage Orientation	:	180°	
Alignment Results	:	Self-aligning grips used.	
Cross-Head Speed (in/min)	:	0.005	
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	
Significance	:	ASTM D7291 specifies that stress and modulus be reported to 3 significant figures.	

Test Number	Sample Diameter (in)	Maximum Load Achieved (lbs)	Max Flatwise Tensile Stress (PSI)	Flatwise Tensile Modulus 0.033% - 0.067% (PSI)	Failure Mode
1	1.000	2080	2640	2080000	SA (Cohesive)
2	1.001	2000	2540	1870000	SA (Cohesive)
3	1.000	1990	2540	1910000	SA (Cohesive)
4	1.000	1910	2430	1960000	SA (Cohesive)
5	1.001	1830	2320	1870000	SA (Cohesive)
Average		**1960**	**2490**	**1940000**	
Std Dev		95	122	87600	
C.O.V. (%)		5	5	5	

Failure Mode

SG - along a single plane within the gage section of the specimen
MG - along multiple planes within the gage section of the specimen
SA - partly through the specimen surface ply or plies and partly through the adhesive
AB - adhesive failure along bond line

Note: The (SA) and (AB) failure modes are not acceptable failure modes and the strength data shall be noted as invalid.

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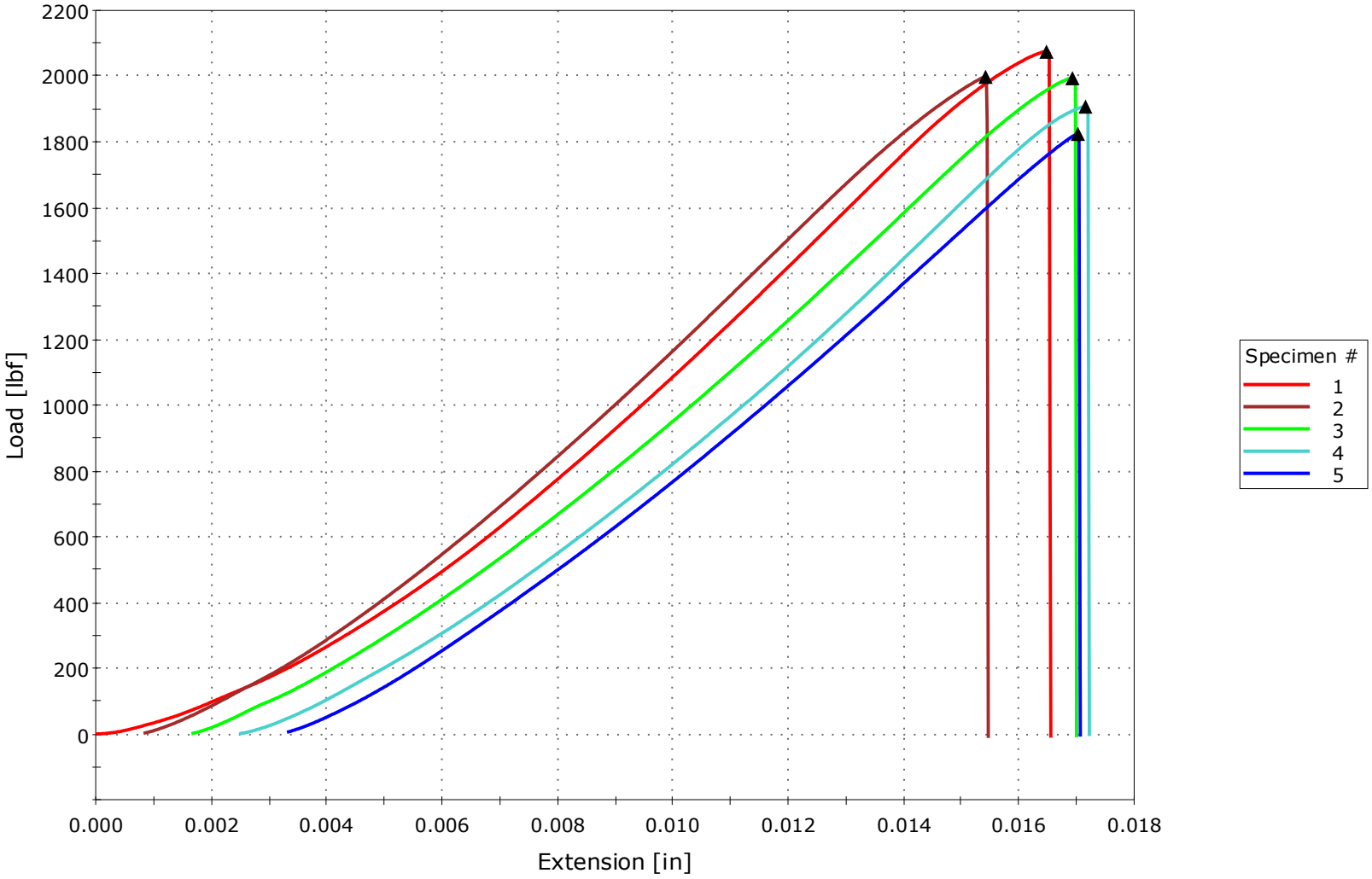
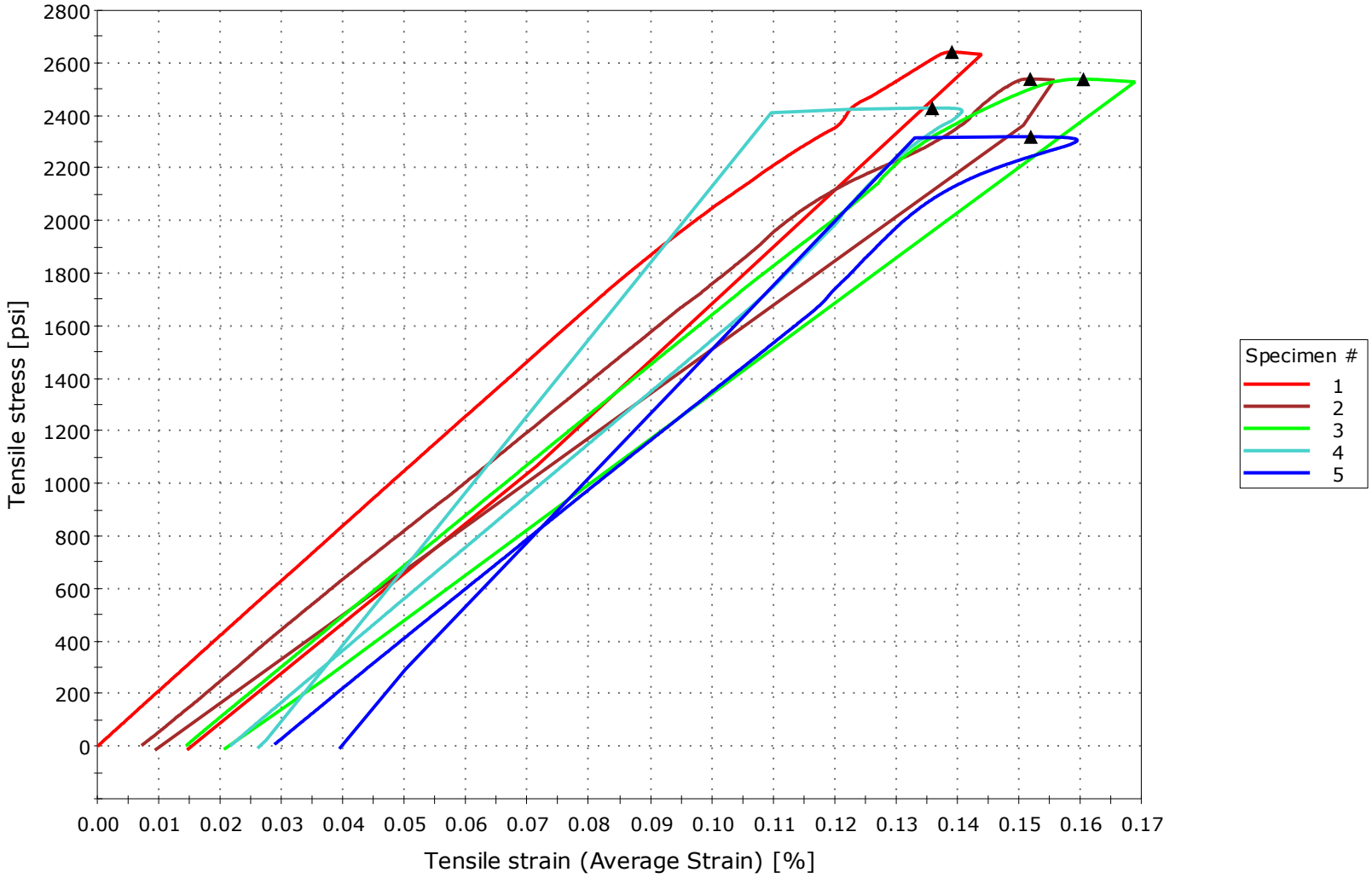


P20170093, ASTM D7291 Flatwise Tensile, MPT-007-006-005



Testing	:	**Through-Thickness "Flatwise" Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material**	
Test Method	:	ASTM D7291/D7291M-15	
Project Number	:	P20170093	Purchase Order: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M.Brady	Attachments: 2 Graphs
Date	:	February 24, 2017	

Material / Sample Name	:	**MPT-007-006-007**	
Ply Orientation / Stacking Sequence	:	Not provided	
Average Ply Thickness	:	Not provided	
Sample Preparation	:	Machined by Intertek PTL using a diamond grit wet saw. Post-bond machining performed by an approved outside source	
Sample Bonding	:	Bonded to loading fixtures using Cybercryl 800	
Tab Dimensions	:	1.0" diameter	
Tab Material	:	Steel	
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	648	Calibration Date : November 2016
Measurement Equipment	:	308	Calibration Date : January 2017
Strain Gage Model Number	:	HBM 1-LY71-3/350	
Strain Gage Orientation	:	180°	
Alignment Results	:	Self-aligning grips used.	
Cross-Head Speed (in/min)	:	0.005	
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	

Test Number	Sample Diameter (in)	Maximum Load Achieved (lbs)	Max Flatwise Tensile Stress (PSI)	Flatwise Tensile Modulus 0.034% - 0.068% (PSI)	Failure Mode
1	1.000	1850	2350	2160000	SA (Cohesive)
2	1.000	1950	2490	1870000	SA (Cohesive)
3	0.998	1910	2440	1850000	SA (Cohesive)
4	1.000	1920	2440	2010000	SA (Cohesive)
5	1.000	1890	2400	1940000	SA (Cohesive)
	Average	**1900**	**2420**	**1970000**	
	Std Dev	37	52	125000	
	C.O.V. (%)	2	2	6	

Failure Mode

SG - along a single plane within the gage section of the specimen
MG - along multiple planes within the gage section of the specimen
SA - partly through the specimen surface ply or plies and partly through the adhesive
AB - adhesive failure along bond line

Note: The (SA) and (AB) failure modes are not acceptable failure modes and the strength data shall be noted as invalid.

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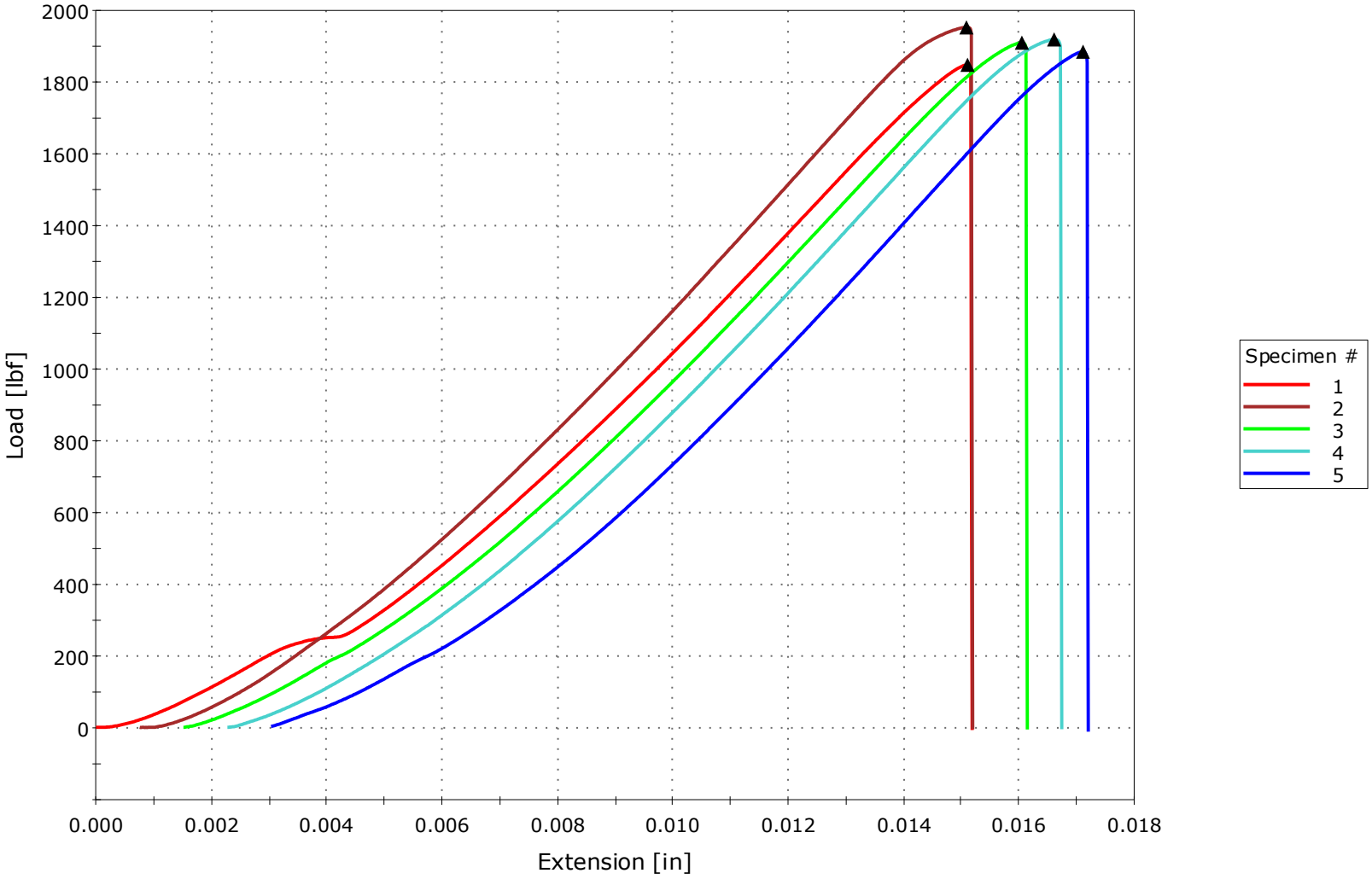
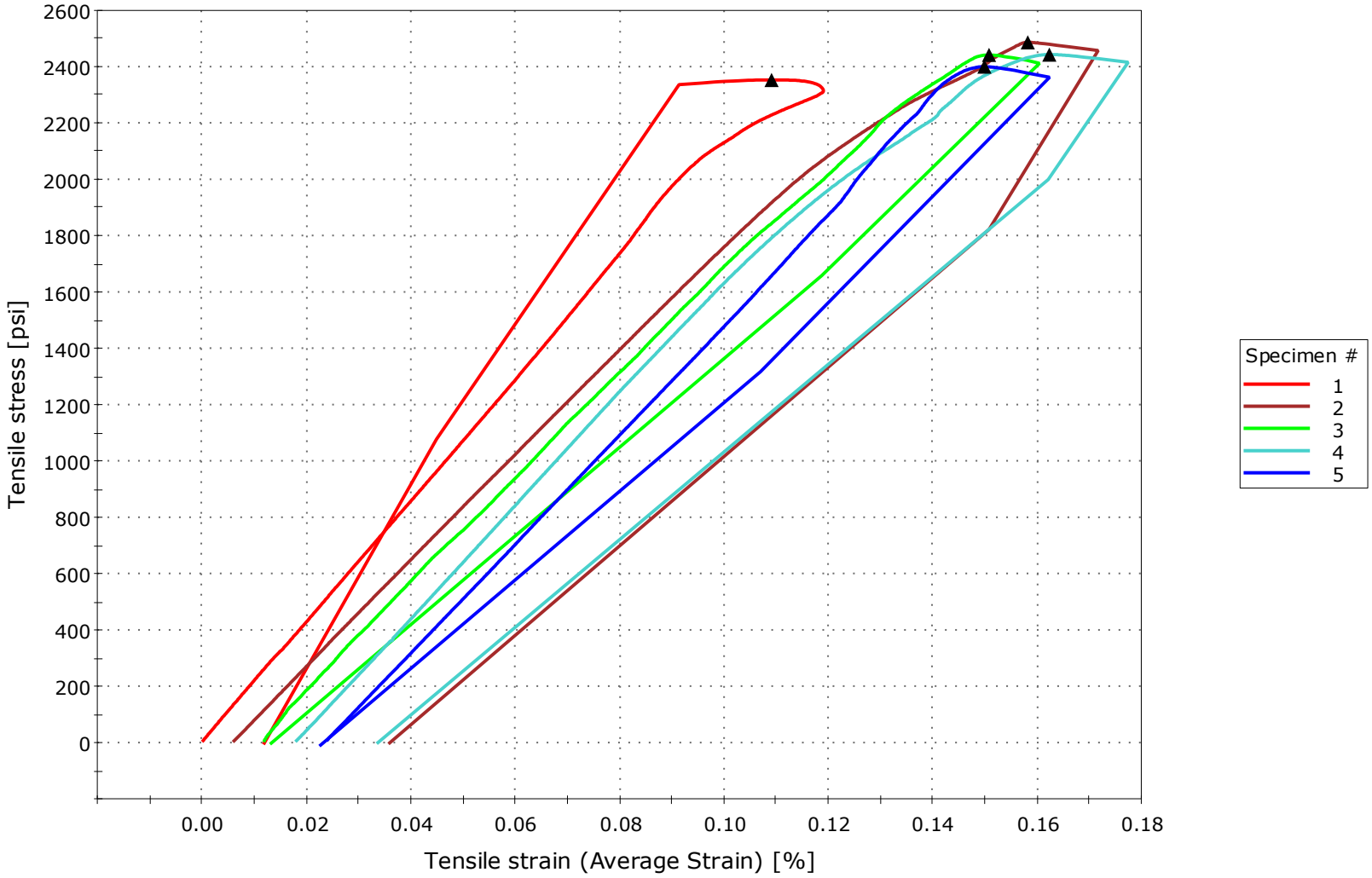


P20170093, ASTM D7291 Flatwise Tensile, MPT-007-006-007



Testing	:	**Through-Thickness "Flatwise" Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material**	
Test Method	:	ASTM D7291/D7291M-15	
Project Number	:	P20170093	Purchase Order: 4601885344
Customer	:	US Army RDECOM-ARDEC Benet Labs	
Attention	:	Andrew Littlefield	
Analyst	:	M. Brady	Attachments: 1 Graph
Date	:	February 27, 2017	

Material / Sample Name	:	**MPT-007-006-008**	
Ply Orientation / Stacking Sequence	:	Not provided	
Average Ply Thickness	:	Not provided	
Sample Preparation	:	Machined by Intertek PTL using a diamond grit wet saw. Post-bond machining performed by an approved outside source	
Sample Bonding	:	Bonded to loading fixtures using Cybercryl 800	
Tab Dimensions	:	1.0" diameter	
Tab Material	:	Steel	
Instron Model Number	:	5985	Calibration Date : January 2017
Measurement Equipment	:	648	Calibration Date : November 2016
Measurement Equipment	:	308	Calibration Date : January 2017
Alignment Results	:	Self-aligning grips used.	
Cross-Head Speed (in/min)	:	0.005	
Sampling Rate (data points/s)	:	20	
Conditioning	:	Unconditioned	
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH	

Test Number	Sample Diameter (in)	Maximum Load Achieved (lbs)	Max Flatwise Tensile Stress (PSI)	Failure Mode
1	0.999	2140	2730	SA (Cohesive)
2	1.000	2070	2630	SA (Cohesive)
3	1.000	2100	2670	SA (Cohesive)
4	1.001	2170	2760	SA (Cohesive)
6	1.000	2110	2690	SA (Cohesive)
	Average	**2120**	**2700**	
	Std Dev	38	51	
	C.O.V. (%)	2	2	

Failure Mode

SG - along a single plane within the gage section of the specimen
MG - along multiple planes within the gage section of the specimen
SA - partly through the specimen surface ply or plies and partly through the adhesive
AB - adhesive failure along bond line

Note: The (SA) and (AB) failure modes are not acceptable failure modes and the strength data shall be noted as invalid.

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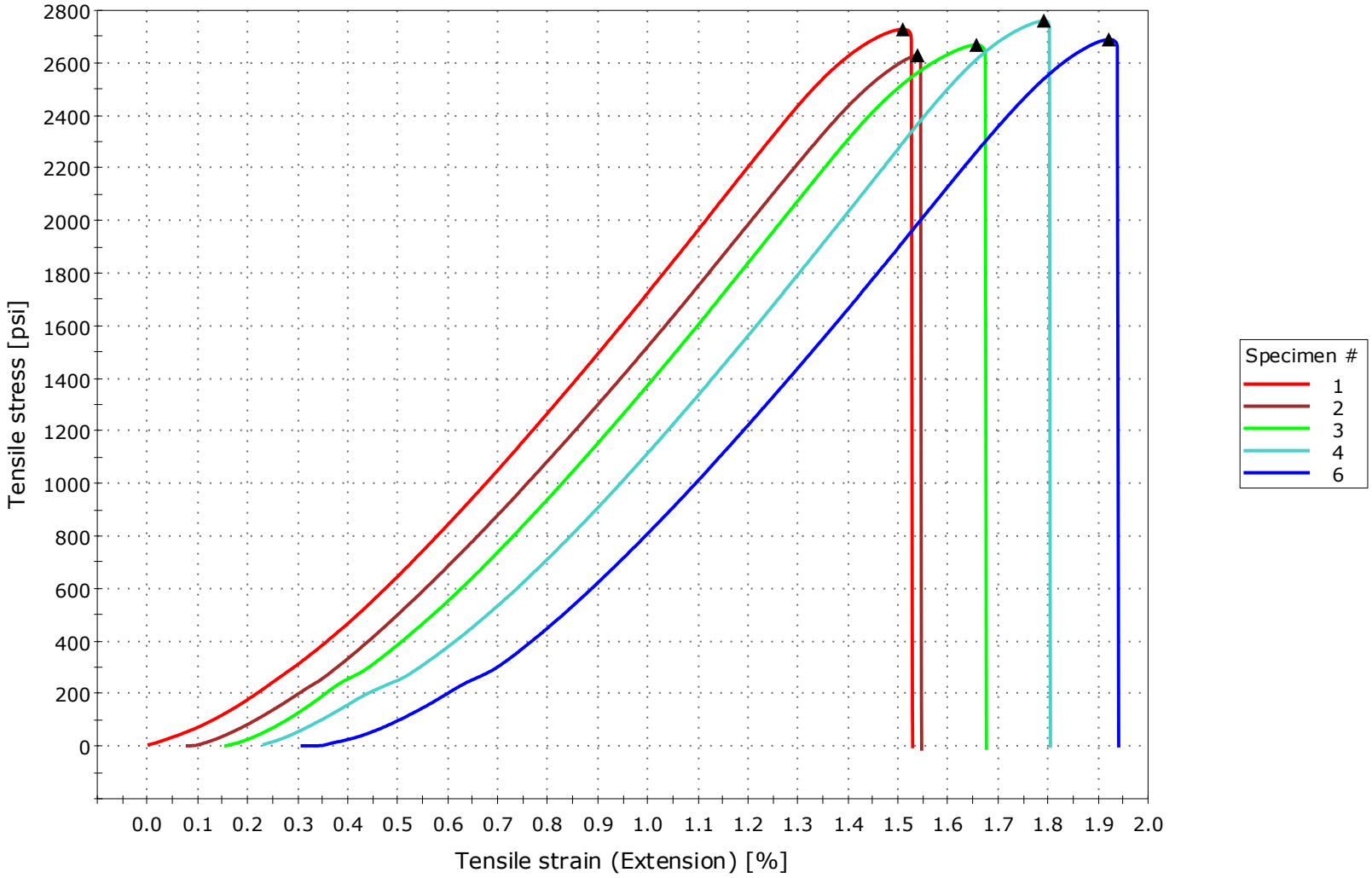


Appendix II

3Tex Panels

For the flat plates

- **0.5" thick - 8 warp/9 fill layer fabric, 22 dpi, 11 ppi**
- **0.38" thick - 6 warp/7 fill layer fabric, 22 dpi, 11 ppi**

	Yarn	V_f
Warp	Toho Tenax HTS 12k	25%
Fill	2 Toho Tenax HTS 6k in layers 1 and 9 2 Toho Tenax HTS 12k in all other layers	25%
Z	Toho Tenax HTS 1k	2%
	Total	52%

I believe that this is what is now known as HTS40 with a Tensile Strength of 4400 MPa and a modulus of 240 GPa

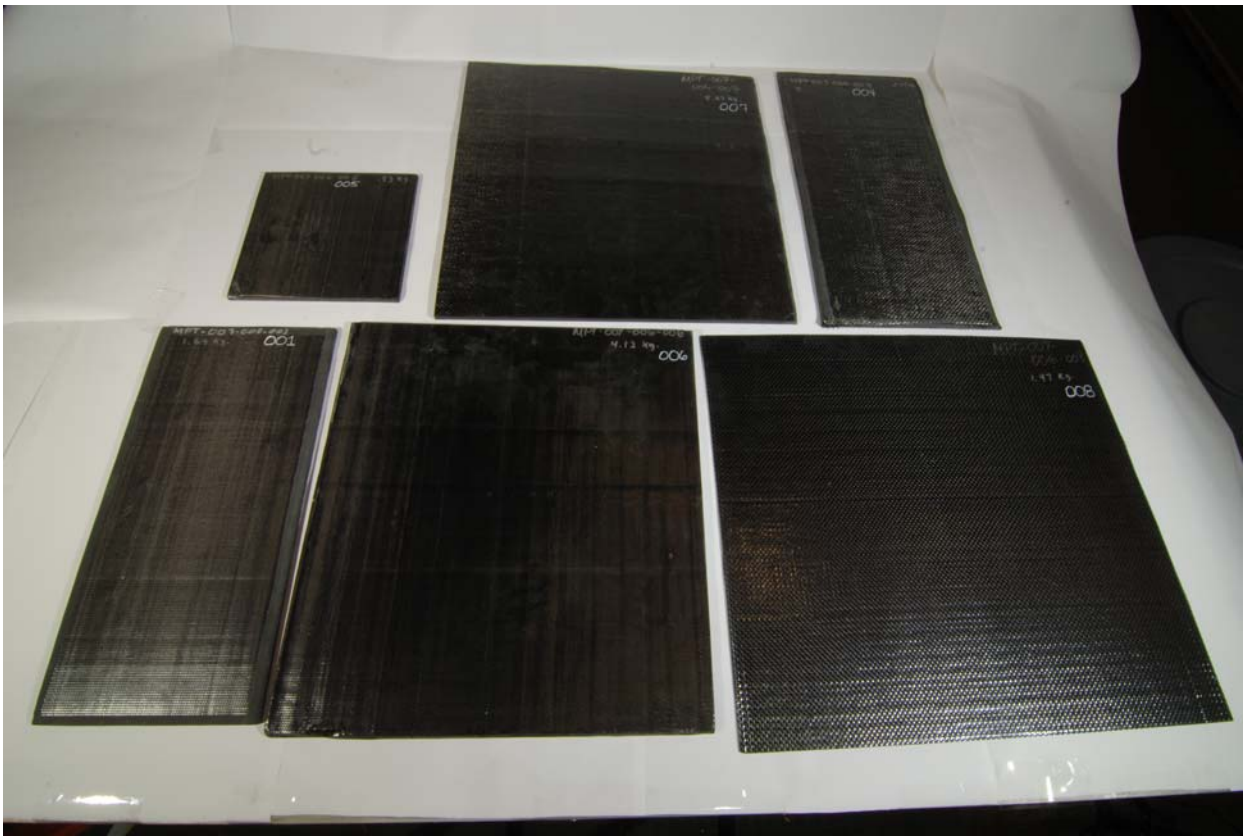
TEAM Panels

Parameter	0030-01BP	0030-01FC
Description	Base Weave - Backplate	Base Weave - Facesheet
Weave Architecture	Orthogonal	Othogonal
Warp and Fill Fiber[1]	T700 12K	T700 12K
Z Fiber	T700 6K	T700 6K
Thickness (as woven)	0.45"	0.14"
Fiber Volume[2]	47% @ 0.45" thick	47% @ 0.14" thick
X:Y:Z Ratio[2]	48:48:05	34:51:15

[1]multiple ends of 12K used in each site
[2]fiber volume and x:y:z ratio are estimates based on TEAM Inc. unit cell model

I believe that this is what is now known as T700S with a Tensile Strength of 4900 MPa and a modulus of 230 GPa

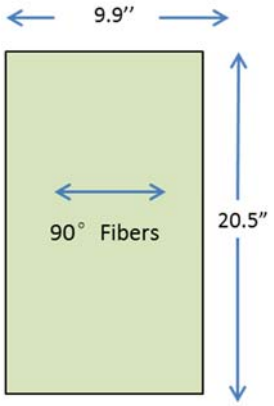
ID #	Size
MPT-007-006-001	20.75” x 9.875” x 3/8”
MPT-007-006-004	23.75” x 11.25” x 0.5”
MPT-007-006-005	10.25” x 10” x 3/8”
MPT-007-006-006	20” x 21.5” x 3/8”
MPT-007-006-007	22” x 23.5” x 3/8”
MPT-007-006-008	22” x 24.5” x 1/8”



MPT-007-006-001, CART/ MBP, Mortar Base Plate Test Panel

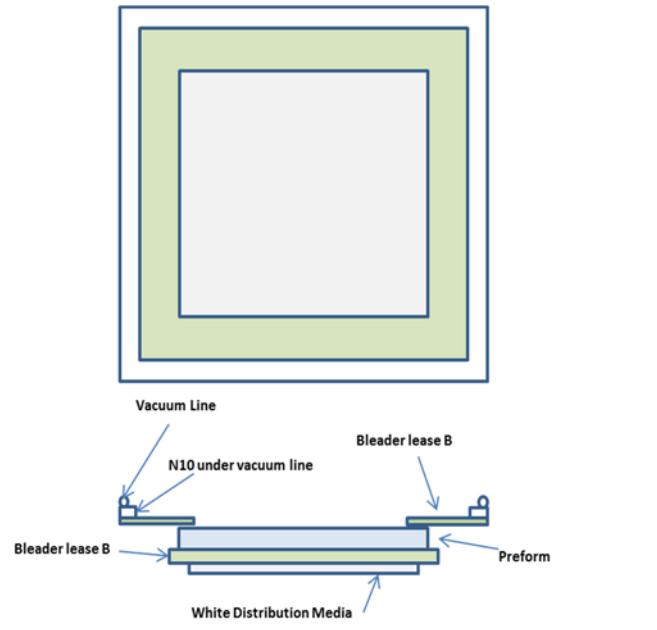
Purpose: Layup and infuse a 3D carbon panel woven by 3TEX with Endurance 4505A epoxy resin.

Ply orientation/rosette: As shown below, the 90° fibers are aligned with the panel Width.



I. Materials List

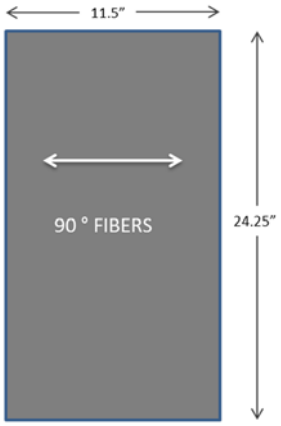
- Endurance 4505A resin, Endurance 4506B hardener.
- (1) 3TEX Base Plate Test Panel : 20.5" in the warp fiber direction x 9.9" in the transverse direction
- (1) Bleederlease B (Green Peel Ply) 21" x 10.5"
- (1) white distribution media 19.5"x 9"
- (1) Dahltex Breather Ply SP (membrane) for rapping the vacuum line: 140" x 5"
- (4) strips of Bleeder lease B (green peel ply): (2) 32"x 6.5" and (2) 32" x 11.5" , see figure below.
- (4) strips of N10 breather: 32"x 2" , see figure below.
- Tacky Tape, Cloth Tape, Nylon Bagging Film, 1/2" spiral tubing etc...



MPT-007-006-004, CART/ MBP, Team Mortar Base Plate Test Panel #4

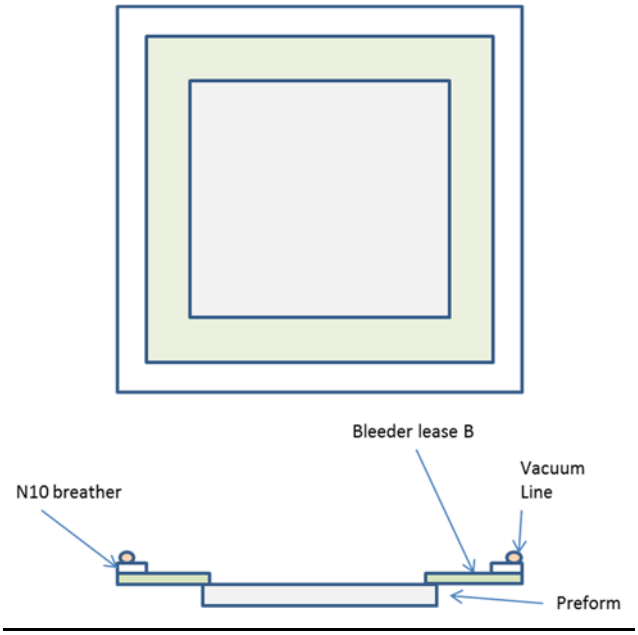
Purpose: Layup and infuse a 3D carbon panel woven by Team with Endurance 4505A epoxy resin.

Ply orientation/rosette: As shown below, the 90° fibers are aligned with the panel Width.



I. Materials List

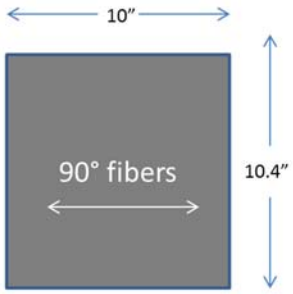
- Endurance 4505A resin, Endurance 4506B hardener.
- (1) Team Base Plate Test Panel : 24.25" in the warp fiber direction x 11.5" in the transverse direction
- (1) Dahltex Breather Ply SP (membrane) for rapping the vacuum line: 140" x 5"
- (4) strips of Bleeder lease B (green peel ply): (2) 32" x 10.75" and (2) 32" x 4.5" , see figure below.
- (4) strips of N10 breather: 32"x 2" , see figure below.
- (1) White DM: 1" x 1"
- (1) Bleaderlease B (green Peel Ply): 2" x 2"
- Tacky Tape, Cloth Tape, Nylon Bagging Film, 1/2" spiral tubing etc...



MPT-007-006-005, CART/ MBP, Small 3Tex Mortar Base Plate Test Panel #5

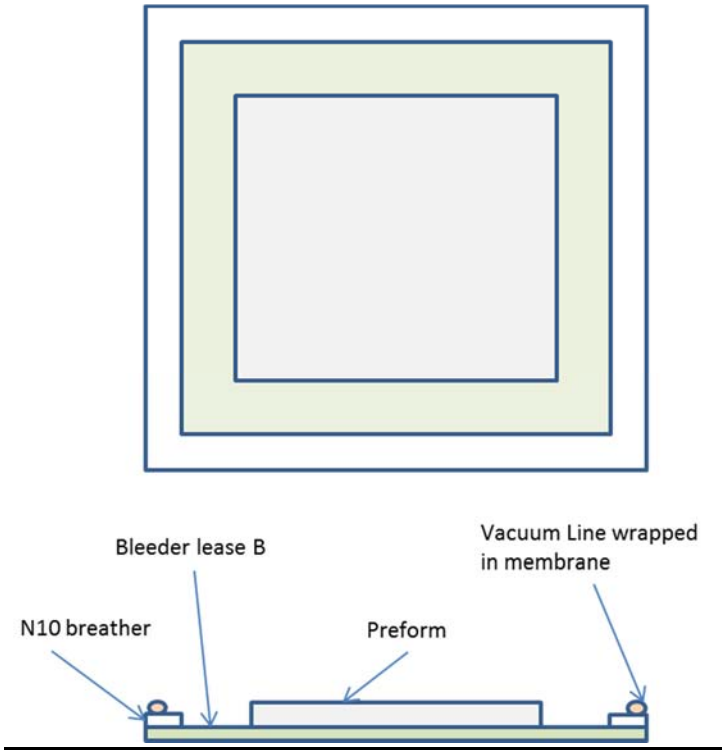
Purpose: Layup and infuse a 3D carbon panel woven by 3TEX with Endurance 4505A epoxy resin.

Ply orientation/rosette: As shown below, the 90° fibers are aligned with the panel Width.



I. Materials List

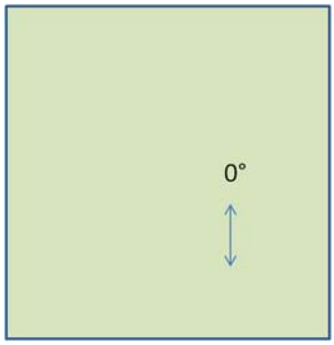
- Endurance 4505A resin, Endurance 4506B hardener.
- (1) 3TEX Base Plate Test Panel : 10.4" in the warp fiber direction x 10" in the transverse direction
- (1) Dahltex Breather Ply SP (membrane) for rapping the vacuum line: 140" x 5"
- (1) Bleeder lease B (green peel ply): (1) 32" x 32", see figure below.
- (4) strips of N10 breather: 32"x 2" , see figure below.
- Tacky Tape, Cloth Tape, Nylon Bagging Film, 1/2" spiral tubing etc...



MPT-007-006-006, CART/ MBP, 3TEX Mortar Base Plate Witness Panel

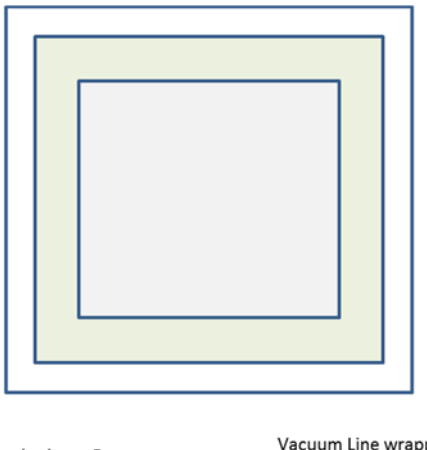
Purpose: Layup and infuse a 3D carbon panel woven by 3TEX with Endurance 4505A epoxy resin.

Ply orientation/rosette: As shown below, the 90° fibers are aligned with the panel Width.



I. Materials List

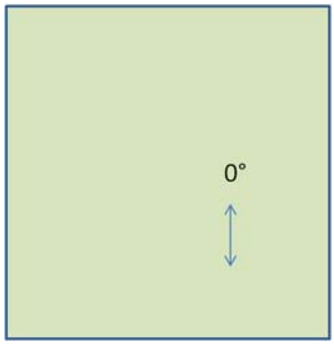
- Endurance 4505A resin, Endurance 4506B hardener.
- (1) 3TEX Base Plate Test Panel : 0.4” thick x 22” in the warp fiber direction x 19.75” in the transverse direction
- (1) Bleederlease B (Green Peel Ply) 32” x 32”
- (1) white distribution media 21”x 18.75”
- (1) Dahltex Breather Ply SP (membrane) for rapping the vacuum line: 140” x 5“
- (4) strips of N10 breather: 32”x 2” , see figure below.
- Tacky Tape, Cloth Tape, Nylon Bagging Film, 1/2" spiral tubing etc...



MPT-007-006-007, CART/ MBP, TEAM Mortar Base Plate Witness Panel

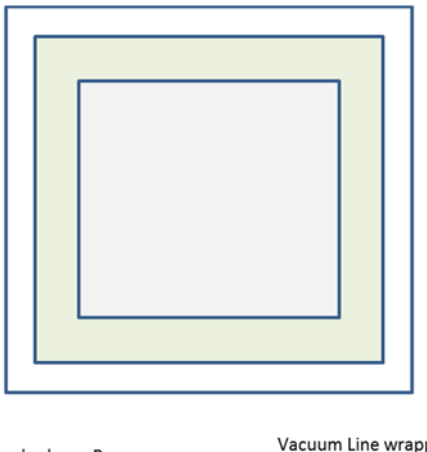
Purpose: Layup and infuse a 3D carbon panel woven by TEAM with Endurance 4505A epoxy resin.

Ply orientation/rosette: As shown below, the 90° fibers are aligned with the panel Width.



I. Materials List

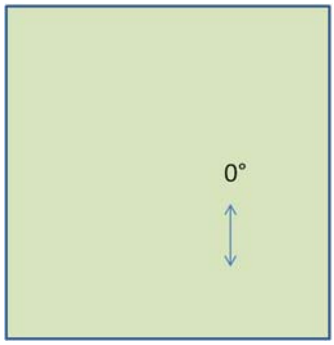
- Endurance 4505A resin, Endurance 4506B hardener.
- (1) TEAM Base Plate Test Panel : 0.43” thick x 23.5” in the warp fiber direction x 23.5” in the transverse direction
- (1) Bleederlease B (Green Peel Ply) 32” x 32”
- (1) white distribution media 22.5”x 22.5”
- (1) Dahltex Breather Ply SP (membrane) for rapping the vacuum line: 140” x 5“
- (4) strips of N10 breather: 32”x 2” , see figure below.
- Tacky Tape, Cloth Tape, Nylon Bagging Film, 1/2" spiral tubing etc...



MPT-007-006-008, CART/ MBP, TEAM Mortar Base Plate Witness Panel

Purpose: Layup and infuse a 3D carbon panel woven by TEAM with Endurance 4505A epoxy resin.

Ply orientation/rosette: As shown below, the 90° fibers are aligned with the panel Width.



I. Materials List

- Endurance 4505A resin, Endurance 4506B hardener.
- (1) TEAM Base Plate Test Panel : 0.14” thick x 22.75” in the warp fiber direction x 24.5” in the transverse direction
- (1) Bleederlease B (Green Peel Ply) 32” x 32”
- (1) white distribution media 21.75”x 23.5”
- (1) Dahltex Breather Ply SP (membrane) for rapping the vacuum line: 140” x 5“
- (4) strips of N10 breather: 32”x 2” , see figure below.
- Tacky Tape, Cloth Tape, Nylon Bagging Film, 1/2" spiral tubing etc...