PROCESSING & DESIGN GUIDE

POLYSTRAND™

CONTINUOUS FIBER REINFORCED THERMOPLASTIC COMPOSITES

AVIENT™

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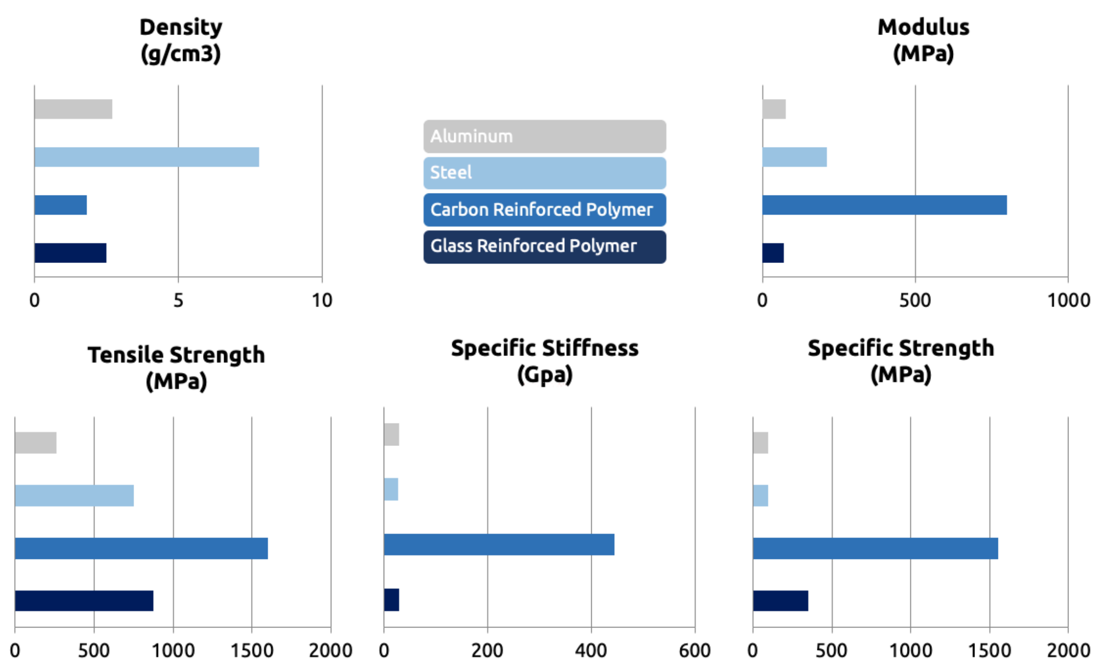
Introduction to Polystrand™ Continuous Fiber Reinforced Thermoplastic Composites

Polystrand™ high performance composite tapes and laminates are made by combining thermoplastic polymers and continuous fibers to create continuous fiber reinforced thermoplastic (CFRTP) composites. This combination yields end products of very high strength and stiffness, excellent fatigue and impact resistance, and light weight. Thermoplastic chemistry enables CFRTP composites to be incorporated into high volume manufacturing processes such as compression and injection molding as well as into structures with dissimilar materials via overmolding, adhesive bonding, and thermal lamination. In combination with other materials, CFRTP materials can be integrated and positioned specifically where needed to achieve structural performance requirements. The material is recyclable and can be incorporated back into traditional thermoplastic products and processes.

Figure 1: Relative Property Comparison



Composite materials, including both thermoplastic as well as traditional thermoset continuous fiber reinforced materials, display high mechanical properties per unit weight compared to aluminum and steel, as shown in Figure 1. However, the use of thermoplastic resins in CFRTP materials allow for both thermal forming and recycling back into thermoplastic compounds, whereas thermoset materials cannot be processed in this manner.

Polystrand materials are manufactured using a variety of base resins, including polyolefins, polyester, and nylon, with reinforcements including E-glass and aramid fibers. This variety of resins and reinforcements allows selection of the most appropriate product for each application. Examples of some standard tape grades are shown in Table 1.

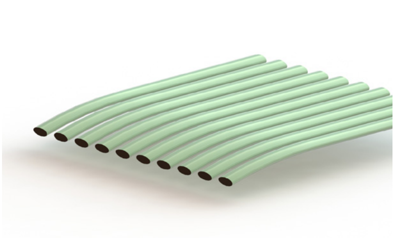
Table 1: Typical Properties - Unidirectional Fiberglass Reinforced Thermoplastic Tape

Product Name	Resin	Fiber Content	Areal Weight			Nominal Thickness[1]		Flexural Modulus ASTM D790		Flexural Strength ASTM D790		Tensile Modulus ASTM D3039		Tensile Strength ASTM D3039	
		wt %	lb/ft^2	oz/yd^2	gsm	in	mm	ksi	GPa	ksi	MPa	ksi	GPa	ksi	MPa
6337	PP	**63**	0.10	14.75	500	0.015	0.38	3570	24.6	58	402	4010	27.6	111	765
6531	PP	**65**	0.05	7.40	251	0.006	0.15	4020	27.7	73	505	4900	33.8	140	965
6536	PP	**65**	0.07	10.32	350	0.009	0.23	4050	27.9	72	494	4500	31.0	131	903
6538	PP	**65**	0.14	19.77	670	0.019	0.48	3540	24.4	47	324	4260	29.4	100	689
7034B	**PP-Black**	**70**	0.07	10.24	347	0.009	0.23	4400	30.3	83	569	5000	34.5	111	765
6020	**PE**	**60**	0.08	11.95	405	0.012	0.30	3600	24.8	54	372	3800	26.2	109	752
6621	**PE**	**66**	0.10	13.97	474	0.012	0.30	4000	27.6	55	379	4720	32.5	126	869
5848	**aPET**	**58**	0.08	11.85	402	0.008	0.20	3900	26.9	94	648	3580	24.7	112	772
5840B	**aPET-Black**	**58**	0.09	13.00	441	0.009	0.23	4120	28.4	107	738	5080	35.0	150	1034

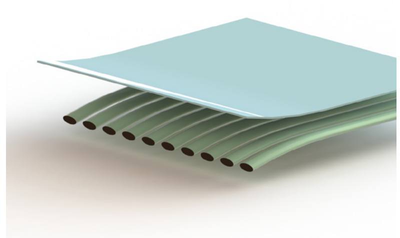
[1] Nominal thicknesses indicated are baseline values that may vary depending on material processing and other variables. Contact Avient with your specific requirements.

Tapes can also be combined to produce laminates of various thicknesses and properties. Examples of possible structures are shown in Figure 2.

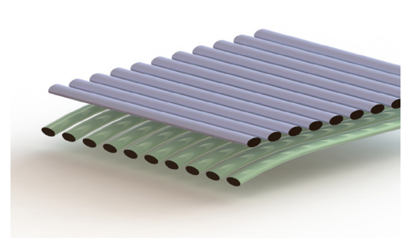
Figure 2: Polystrand Laminate Configurations



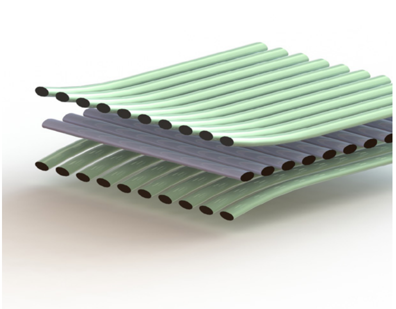
Unidirectional Tape



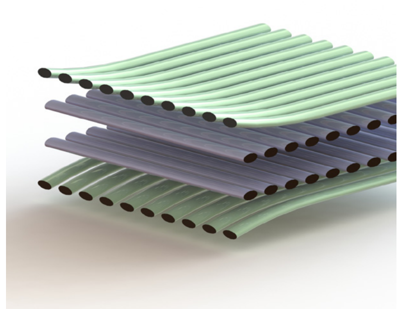
Uni Tape with Scrim



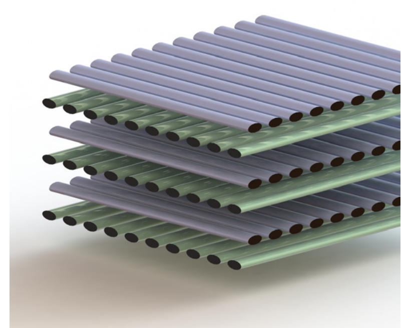
X-Ply™ 0°/90°



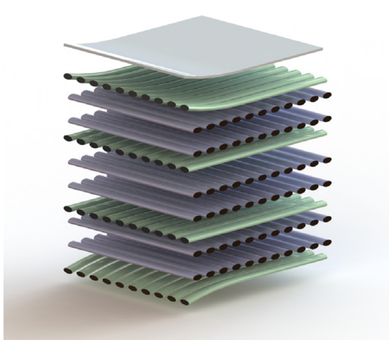
Tri-Ply 0°/90°/0°



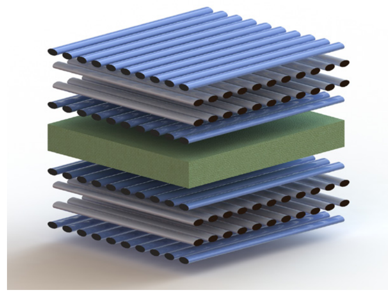
Quad-Ply 0°/90°/90°/0°



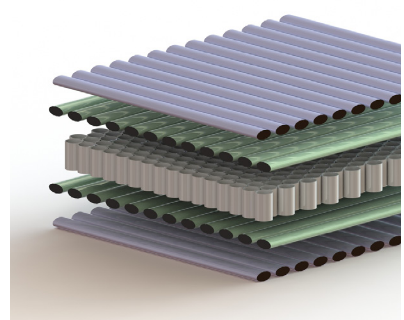
6-Ply



10-Ply with Film



Foam Core, Quad-Ply Skins



Honeycomb Core, X-Ply™ Skins

Properties of various laminates can be found in Table 2. Polystrand materials are available in both unidirectional tapes and multi-ply laminates, and additional films can be incorporated for specific needs such as decoration and UV protection. Tapes and laminates of 4-ply or lower are available in sheet form or in rolls from 2 inches (5 cm) to 10 feet (3 m) in width; thicker sheets are supplied as cut panels. Finished goods such as die cut sheets are also available.

Table 2: Typical Properties - Multi-Axial Laminates

									0° Testing Orientation								90° Testing Orientation							
Product Name	Resin	Fiber Content	Laminate Layers & Orientation	Areal Weight			Nominal Thickness[1]		Flexural Modulus ASTM D790		Flexural Strength ASTM D790		Tensile Modulus ASTM D3039		Tensile Strength ASTM D3039		Flexural Modulus ASTM D790		Flexural Strength ASTM D790		Tensile Modulus ASTM D3039		Tensile Strength ASTM D3039	
		wt %		lb/ft²	oz/yd²	gsm	in	mm	ksi	GPa	ksi	MPa	ksi	GPa	ksi	MPa	ksi	GPa	ksi	MPa	ksi	GPa	ksi	MPa
6337	PP	63	0/90	0.20	29.49	1000	0.031	0.79	-	-	-	-	2020	13.9	59.7	412	-	-	-	-	2020	13.9	59.7	412
			0/90/0	0.31	44.24	1500	0.045	1.14	2250	15.5	46.4	320	3070	21.2	79.4	547	186	1.3	9.7	67	1330	9.2	39.6	273
			0/90/90/0	0.41	58.98	2000	0.057	1.45	2000	13.8	44.0	303	2400	16.5	60.6	418	496	3.4	20.7	143	2210	15.2	56.4	389
6531		65	0/90	0.10	14.80	502	0.014	0.36	-	-	-	-	2240	15.4	60.9	420	-	-	-	-	2240	15.4	60.9	420
			0/90/0	0.15	22.20	753	0.020	0.50	2650	18.3	58.3	402	3100	21.4	82.8	571	280	1.9	NB[2]	NB[2]	1670	11.5	42.5	293
			0/90/90/0	0.21	29.61	1004	0.027	0.68	2260	15.6	51.5	355	2470	17.0	62.2	429	580	4.0	30.4	210	2310	15.9	59.6	411
6536			0/90	0.14	20.71	702	0.021	0.53	-	-	-	-	1980	13.7	60.5	417	-	-	-	-	1980	13.7	60.5	417
			0/90/0	0.22	31.06	1053	0.029	0.74	2309	15.9	48.3	333	2730	18.8	81.5	562	245	1.7	13.0	90	1490	10.3	44.3	305
			0/90/90/0	0.29	41.41	1404	0.037	0.94	2164	14.9	47	324	2170	15.0	59.6	411	512	3.5	25.4	175	2340	16.1	71.2	491
6538			0/90	0.27	39.54	1341	0.034	0.86	-	-	-	-	2220	15.3	60.0	414	-	-	-	-	2220	15.3	60.0	414
			0/90/0	0.41	59.53	2018	0.057	1.44	2825	19.5	40.9	282	2780	19.2	67.6	466	218	1.5	10.2	70	1410	9.7	40.0	276
			0/90/90/0	0.55	79.37	2691	0.073	1.85	1880	13.0	32.4	223	2060	14.2	54.0	372	478	3.3	18.0	124	2360	16.3	61.0	421
7034B	PP-Black	70	0/90	0.14	20.48	694	0.016	0.40	-	-	-	-	2680	18.5	62.0	427	-	-	-	-	2680	18.5	62.0	427
			0/90/0	0.21	30.72	1041	0.028	0.71	1750	12.1	55.9	385	3710	25.6	75.1	518	160	1.1	11.3	78	1440	9.9	36.2	250
			0/90/90/0	0.28	40.95	1388	0.036	0.90	1700	11.7	40.4	279	2800	19.3	55.7	384	432	3.0	25.4	175	2350	16.2	52.4	361
6020	PE	60	0/90	0.17	23.90	810	0.023	0.57	-	-	-	-	1830	12.6	52.00	359	-	-	-	-	1830	12.6	52.0	359
			0/90/0	0.25	35.86	1216	0.033	0.84	2265	15.6	40.0	276	2740	18.9	68.2	470	181	1.2	10.0	69	1350	9.3	35.3	243
			0/90/90/0	0.33	47.81	1621	0.044	1.12	1810	12.5	30.0	207	2000	13.8	48.0	331	502	3.5	22.0	152	1820	12.5	46.0	317
6621		66	0/90	0.19	27.94	947	0.025	0.65	-	-	-	-	2280	15.7	60.0	414	-	-	-	-	2280	15.7	60.0	414
			0/90/0	0.29	41.90	1421	0.040	1.01	2490	17.2	37.0	255	2900	20.0	70.0	483	165	1.1	9.7	67	1440	9.9	38.0	262
			0/90/90/0	0.39	55.87	1894	0.053	1.35	1810	12.5	29.0	200	2160	14.9	58.0	400	508	3.5	21.0	145	2170	15.0	53.0	365
5848	aPET	58	0/90	0.17	24.26	822	0.020	0.50	-	-	-	-	2190	15.1	65.0	448	-	-	-	-	2100	14.5	57.8	399
			0/90/0	0.25	36.38	1233	0.030	0.76	2963	20.4	112.3	774	2900	20.0	87.5	603	279	1.9	13.2	91	1366	9.4	35.7	246
			0/90/90/0	0.34	48.51	1645	0.040	1.02	2848	19.6	103.6	714	2106	14.5	64.7	446	947	6.5	33.4	230	2089	14.4	55.8	385
5840B	aPET-Black	58	0/90	0.18	26.01	882	0.021	0.53	-	-	-	-	2530	17.4	55.3	381	-	-	-	-	2530	17.4	55.3	381
			0/90/0	0.27	39.01	1323	0.032	0.82	2986	20.6	91.1	628	3160	21.8	68.7	474	252	1.7	20.0	138	1580	10.9	36.9	254
			0/90/90/0	0.36	52.01	1763	0.042	1.07	3065	21.1	73.1	504	2570	17.7	54.2	374	813	5.6	37.0	255	2440	16.8	55.6	383

[1] Nominal thicknesses indicated are baseline values that may vary depending on material processing and other variables. Contact Avient with your specific requirements.
[2] No break occurred in testing.

Laminate Construction and Properties

DESIGNING FOR STRENGTH AND STIFFNESS

A composite laminate is a combination of unidirectional composite tapes layered in off-axis orientations, most commonly in 0- and 90-degree arrangements. This is done by stacking layers of materials in the desired orientation and consolidating them by applying heat and pressure. The strength and stiffness of the finished composite are affected by three key variables that should be considered when designing a laminate material: **fiber orientation, fiber location,** and **fiber volume.**

FIBER ORIENTATION

Strength can be optimized by orienting the high modulus composite fibers longitudinally (in the direction of the load that the laminate will experience in use). When loading is perpendicular—or transverse—to the fiber, the polymer matrix is primarily resisting the load, rather than the fibers. Because the resin has lower strength and stiffness than the fibers, the composite will deform more easily and fracture at lower loads compared to a laminate that is loaded in the direction of the fibers. Figures 3 and 4 illustrate how orienting the fibers in the direction of the load can improve strength in that direction.

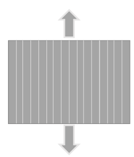
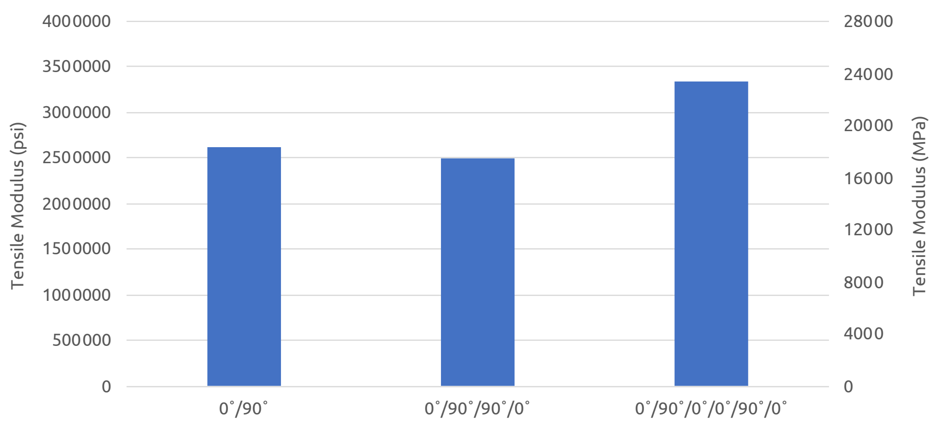


Figure 3: Tensile Modulus – Longitudinal Loading



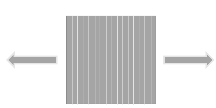
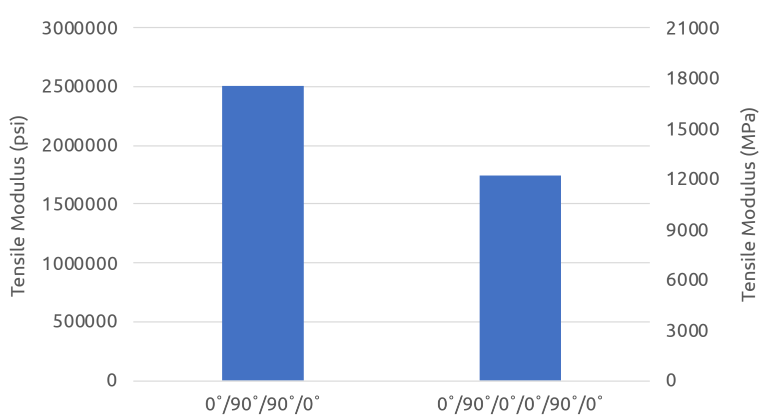


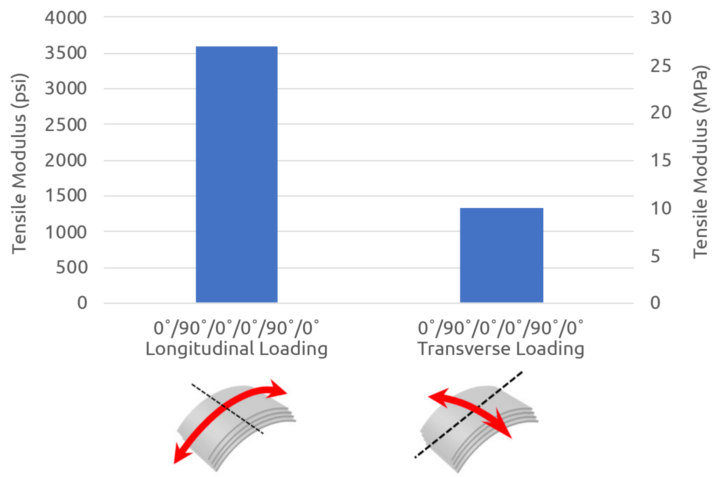
Figure 4: Tensile Modulus – Transverse Loading



FIBER LOCATION

The direction and location of the fibers in the laminate construction have a significant effect on the finished composite's resistance to bending, measured as flexural modulus. As illustrated in Figure 5, 6-ply laminate samples had flexural loads applied in both the longitudinal and transverse directions. The 6-ply sample has the highest flexural modulus when loaded in the longitudinal direction due to the higher ratio of 0-degree layers, as well as the location of the 0-degree fibers outside of the neutral axis. This same laminate configuration loaded in the transverse direction exhibits much lower flexural performance because there are fewer transversely oriented fibers to resist the bending load.

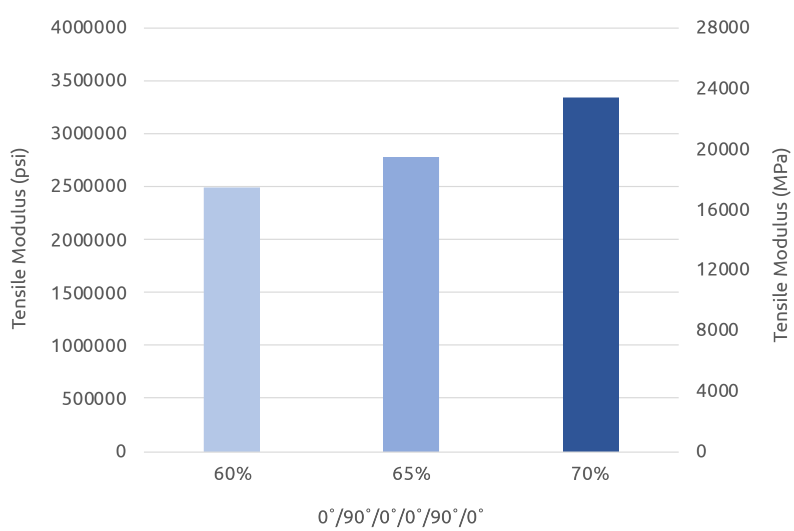
Figure 5: Flexural Modulus – Longitudinal & Transverse Loading



FIBER CONTENT

Fiber content can be designated by either volume percentage or weight percentage. Avient specifies fiber content for Polystrand materials as a weight percentage basis, which can be mathematically converted to a volume percentage basis if needed. Increasing the fiber content of a composite generally increases its mechanical performance (within practical limits), as illustrated in Figure 6. In general, the more fiber in a structure, the higher the performance. CFRTP composite materials can be produced with fiber weight percentages ranging from 58% to 80% in order to achieve specific performance requirements depending on the intended application

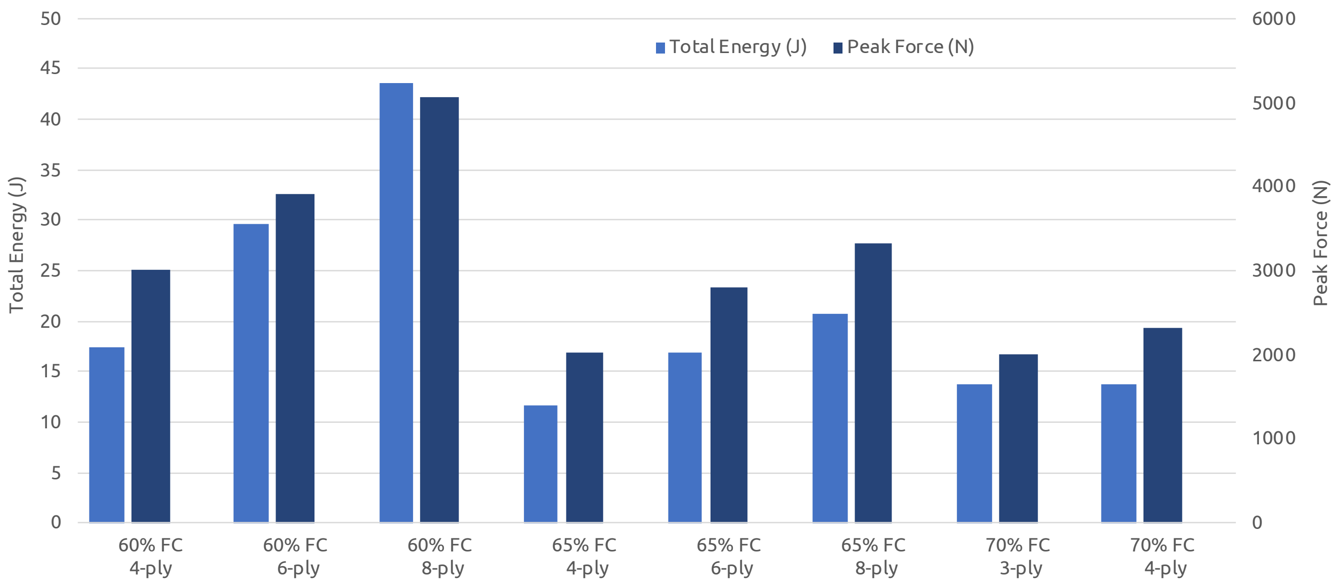
Figure 6: Effect of Fiber Volume on Tensile Modulus



DESIGNING FOR IMPACT RESISTANCE

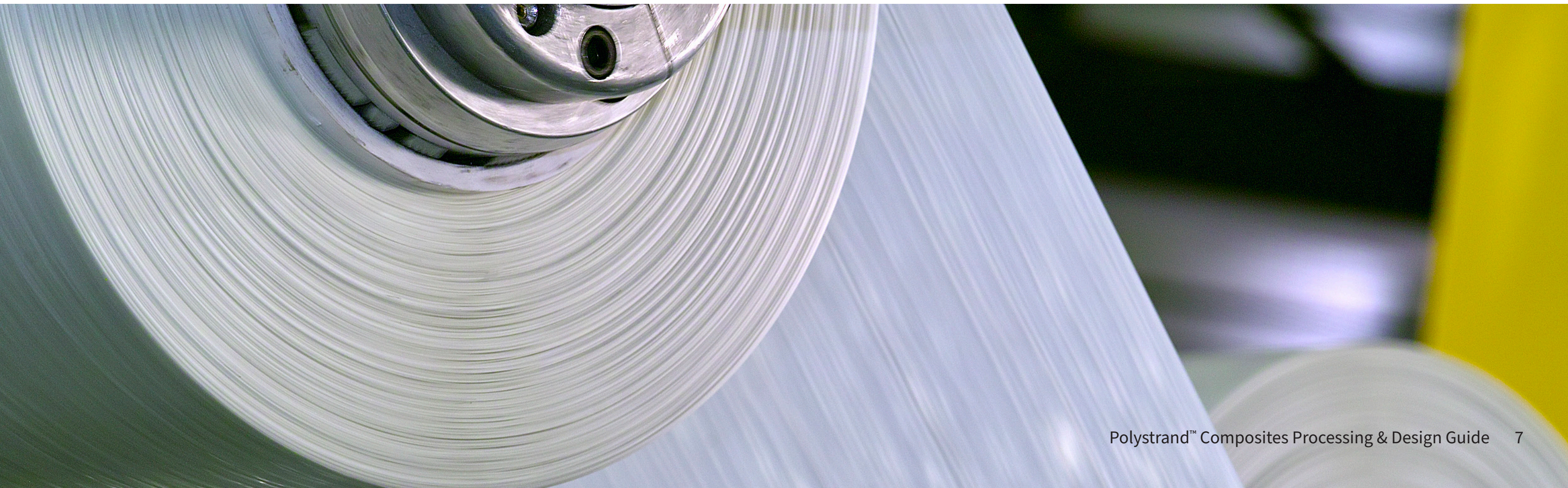
Impact resistance can be similarly optimized through laminate design. Figure 7 illustrates how the addition of composite layers, their relative orientation, and fiber content can influence puncture resistance. Peak Force is the maximum force achieved before the material failed in the test. Total Energy is a calculation that includes force as a component, and is descriptive of how much a material deforms when the impact occurs. Lower fiber content materials generally exhibit greater impact strength than composites with higher fiber content. This is due to the resin's ability to deform much further than glass fiber before failure. More energy is absorbed in the deformation, and impact strength is higher than that of materials with a lower resin to fiber ratio.

Figure 7: Impact Resistance
ASTM D3763



Laminates tested are PP resin with varying fiber count (FC) and laminate layers (plys) as indicated.

For specific applications or load cases, Finite Element Analysis using composite-capable software can be a useful tool to optimize laminate construction and fiber orientation.



Processes and Applications

Polystrand continuous fiber reinforced thermoplastic tapes and laminates can be processed via various thermoforming processes including compression molding, injection and compression overmolding, and hot pressing into contoured forms and flat panels. They can be processed alone or in conjunction with other materials such as thermoplastics, wood, and metal. For shorter or prototype production, they can also be formed via diaphragm molding, rubber stamps, and heated vacuum bag processes. Matched metal tooling is typically preferred for larger-scale production. Trimming of finished parts is often required, and can be accomplished via water jet, sawing, or routing. At a minimum, carbide cutting tools are recommended. Due to the high percentage of fiber content, high performance tooling coatings are recommended to extend tooling life and improve cut quality. For large volume production, PCD (polycrystalline diamond) tooling will provide the highest feed rates and longest tooling life.

MOLDING AND FORMING POLYSTRAND CFRTP

TAPE LAMINATION

Polystrand unidirectional tapes can be laminated into multi-ply sheets using continuous belt laminators and via automated tape placement and static pressing.

Belt processing parameters including zone temperatures, nip heights, and pressures will vary according to the matrix resin, the thickness of the laminate, and the desired throughput. Since these factors are all interrelated, it is recommended to contact Avient for assistance in optimizing this process.

COMPRESSION MOLDING

Compression molding, or stamping, is a commonly used method for producing three-dimensional components using Polystrand laminate materials. Matched metal molds constructed from hardened steel are preferred due to the material's high fiberglass content. Sheets should be oversized and allowed to move freely during the compression step. Selective addition of darts or slit cuts outside the part area can improve replication of part features and corners. Edges typically require trimming to final dimension. Recommended sheet and mold temperatures are shown in Table 3.

Applications include protective covers, vehicle underbody shields, sporting goods, corrugated panels, orthotics, and cargo containers.

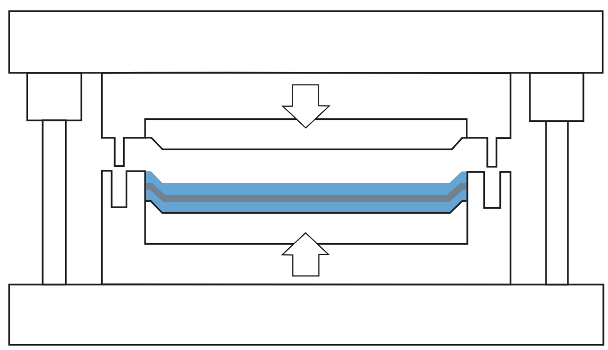


Table 3: Compression Molding Conditions

Base Resin	Forming Temperature		Tool Temperature	
	°F	°C	°F	°C
High Density Polyethylene (PE)	360–400	182–204	68–194	20–95
Polypropylene (PP)	390–430	199–221	68–176	20–80
Polyethylene Terephthalate (PET)	400–500	204–260	50–86	10–30
Polyamide 6 (PA6)	480–530	249–276	176–194	80–90

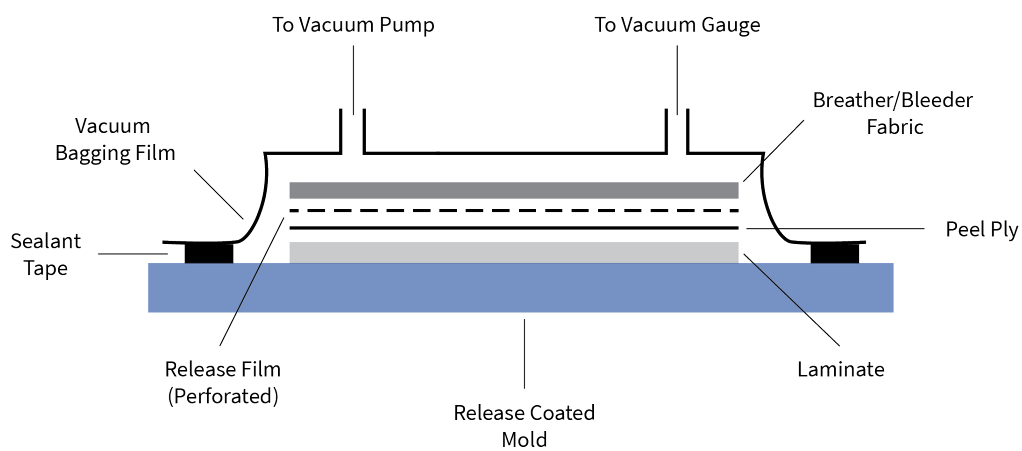
VACUUM AND VACUUM BAG THERMOFORMING

Vacuum and vacuum bag thermoforming are generally used in prototyping for tool validation; for higher volume production, other processes are better suited. Two-dimensional and some modest three-dimensional structures can be produced via these processes provided that the material's edges are not constrained and a finished trimming step is provided.

A typical layout for vacuum bag thermoforming in an oven or autoclave is shown in Figure 8. Sheet temperatures should be set to the lower end of values listed in Table 3: Compression Molding Conditions. High-temperature bags and either perforated or non-perforated release films are recommended. Incorporation of mold release film and breathers is also suggested.

Shallow bowls and open-ended half-cylinders are examples of possible structures that can be created using vacuum thermoforming processes.

Figure 8: Vacuum Bag Thermoforming



BALLISTIC PANELS

High fiber content (approx. 80% by weight) Polystrand tapes can be consolidated into ballistic panels using conventional heated presses and high pressures. This is typically done by stacking multiple cross-plies to a thickness required to meet the desired threat protection. Specific ballistic ratings can be achieved by varying the number of plies or via the use of specialized aramid fiber grades. Consolidated panels of greater than 30 plies are frequently employed in ballistic armor systems.

Suggested forming guidelines are shown in Table 4: Ballistic Panel Processing Parameters. Panels should be heated so that the temperature at the center of the structure reaches the minimum of the temperature range. A thermocouple placed inside the structure during setup is recommended to verify this temperature is achieved. Once the temperature is reached, the panel should be held under the recommended pressure for a minimum of 15 minutes. A slow cool-down is recommended to ensure complete consolidation and minimal residual stress.

Table 4: Ballistic Panel Processing Parameters

Processing Parameters	PP Composite Matrix
Sheet Temperature	365–380°F/185–193°C
Part Removal Temperature	<140°F/<60°C
Drying Temperature (4 hours)	Not Required
Compression Molding Pressure	150–350 psi/1034–2413 kPa

Often, a ballistic panel is constructed with several different materials, e.g. a ceramic or metallic strike face with a Polystrand composite material backing. Very high glass and/or aramid reinforcement levels are most effective in these applications. Aramid is often used in place of glass where weight is of paramount importance, e.g. personal protection vests.

HYBRID CONSTRUCTIONS

Combining Polystrand continuous fiber reinforced thermoplastic composites with materials such as other thermoplastics, wood, or metal can result in significant increases in strength, stiffness, and impact resistance. These gains can, in many cases, enable material reduction or down-gauging of the primary substrate without diminishing performance. Even single-ply tapes applied in the direction of tensile loading can impart dramatic improvements in fatigue life. The high strength-to-weight ratio of Polystrand composites allows the use of less material to achieve desired performance, reducing both raw materials and shipping costs. Water permeability and resistance are also increased, and with selected grades the surface is easily printed or painted.

COMPRESSION MOLDING WITH OTHER THERMOPLASTICS

Polystrand materials can be applied to the outside or embedded within other thermoplastics via compression overmolding. To apply on the exterior, a heated Polystrand sheet is placed against the mold face and a heated charge of polymer is deposited on top. The mold is then closed and compressed to consolidate the part. To embed the laminate inside the part, a molten charge is first deposited on the mold, heated Polystrand material laid on top, additional resin applied, and the entire structure compression molded. Placing on the exterior yields maximum benefit when the surface is subject to high tensile loads. When placed inside the part, a Polystrand sheet provides a reinforcement that increases strength and impact resistance, while allowing good replication of surface features produced by the molding resin. An additional benefit to placing the composite sheet inside the part is reduction of part warpage caused by dissimilar shrink factors. Refer to the guidelines in Table 5 for preheating conditions for each Polystrand resin system, and follow manufacturer recommendations for molding with the overmold resin.

Table 5: Preheating Guidelines

Polystrand Base Resin	Preheat Temperature Range	
	°F	°C
High Density Polyethylene (PE)	260–325	127–163
Polypropylene (PP)	280–350	138–177
Polyester (PET)	400–450	204–232
Polyamide 6 (PA6)	400–450	204–232

INJECTION OVERMOLDING

Polystrand composite tapes and laminates can also be combined with other resins via injection molding processes using conventional molding equipment. The reinforcement can be applied specifically where needed to increase strength, stiffness, and impact performance of the molded article. Polystrand materials exhibit very low shrinkage and thermal expansion, therefore it is helpful to minimize shrinkage of the overmolded resin in order to inhibit warpage of the finished component. The use of fiber or other filled compounds such as long fiber reinforced thermoplastics is preferred. Part design should be optimized via fill and warp analysis. Ribs and frame features are especially effective at stabilizing the composite sheet and minimizing warpage.

To achieve an optimal level of adhesion between the composite and the molding resin, preheating the Polystrand composite blank is required prior to placing in the mold. This is often done with infrared heaters placed press-side and a robot delivering the composite blank from the heater to the mold. Table 5: Preheating Guidelines contains the recommended preheat temperature for each Polystrand material resin system. Once heated to sufficient temperature, the laminate can be overmolded directly or formed during mold close prior to overmolding. See Figure 9 for an illustration of the injection overmolding process.

Laminates can be held in the mold using a variety of techniques. Retractable pins are a common method of holding the laminates, which are retracted during mold close and forming/molding. Vacuum ports can also be employed for flat areas where pins cannot be placed. Polystrand composite blanks can also be formed separately via compression molding and then transferred to an injection tool for overmolding.

Adding Polystrand tapes and laminates to materials such as molding grade thermoplastics boosts strength and stiffness as well as fatigue, impact, and creep resistance. Figures 10 and 11 illustrate some of the performance improvements that can be achieved through overmolding.

Applications for injection overmolded parts include sporting goods, consumer electronics, and components for automotive and transportation.

Figure 9: Injection Overmolding Process

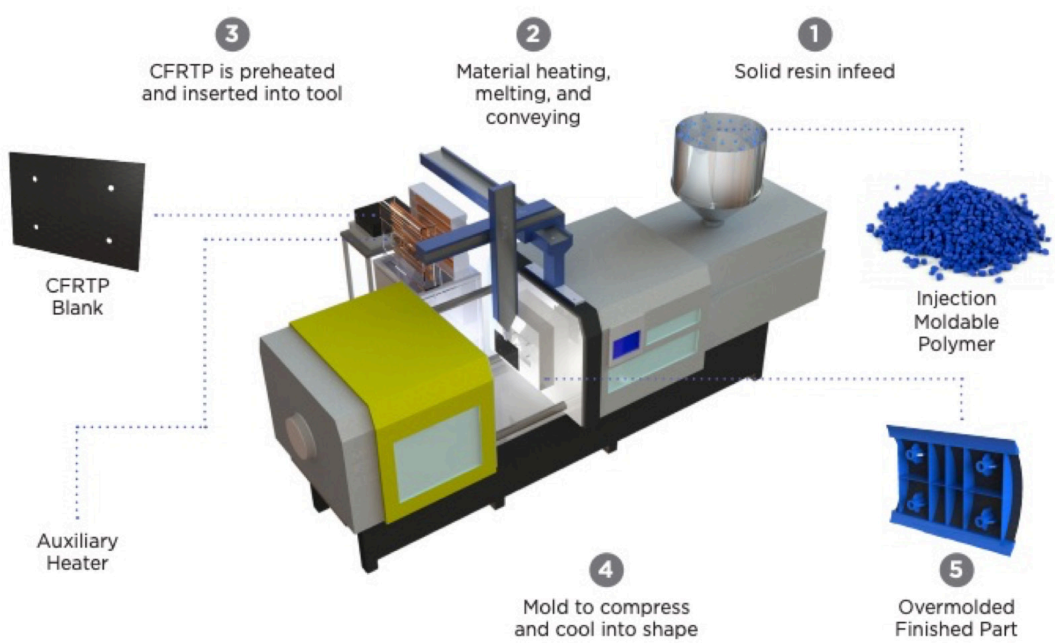
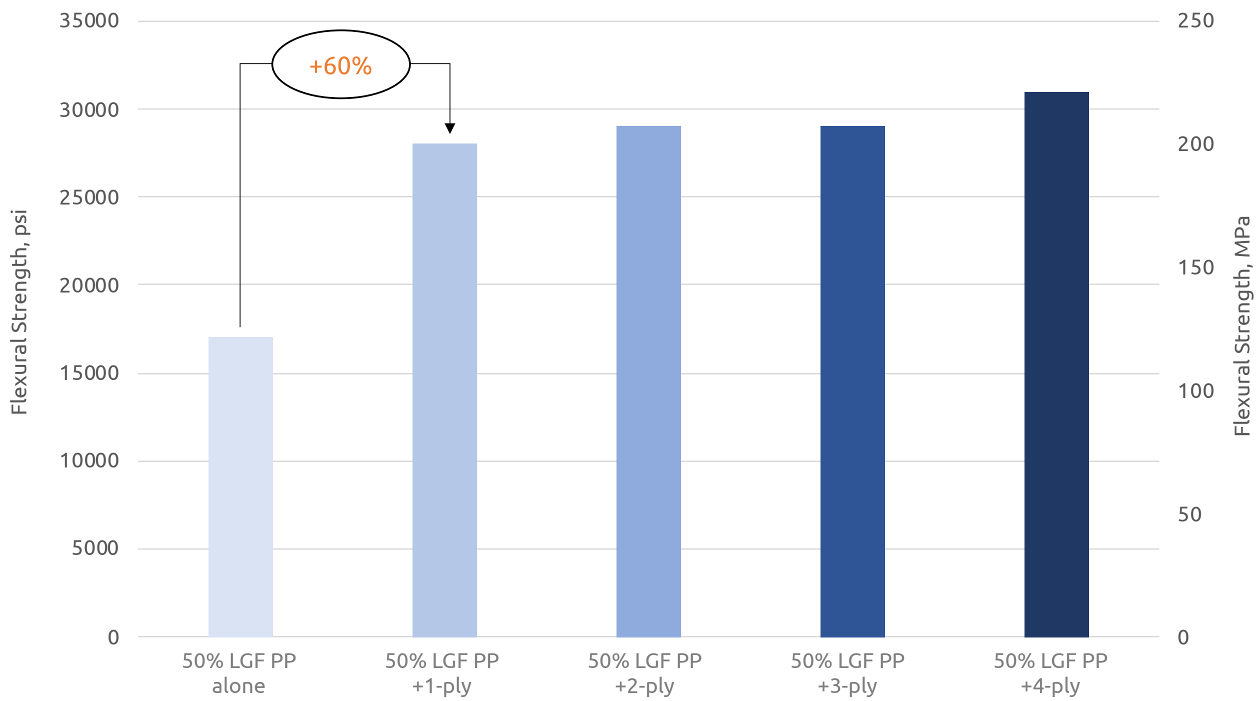
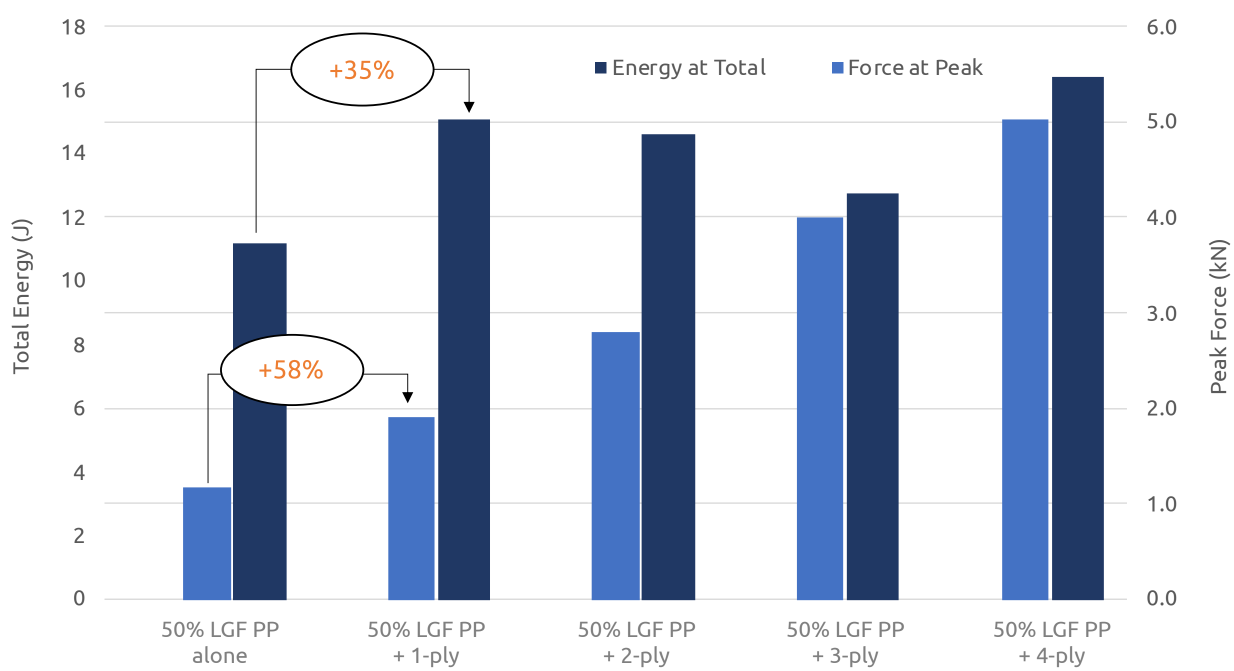


Figure 10: Injection Overmolding Flexural Strength Improvements ASTM D7264



Laminates tested are 50% Long Glass Fiber reinforced (LGF) PP with various CFRTP tape and laminate overmolded reinforcement layers (plys) as indicated.

Figure 11: Injection Overmolding Impact Resistance Improvements ASTM D3763



Laminates tested are 50% Long Glass Fiber reinforced (LGF) PP with various CFRTP tape and laminate overmolded reinforcement layers (plys) as indicated.

WOOD HYBRIDS

Polystrand continuous fiberglass reinforced PET unidirectional tapes and multi-ply laminates can be thermally bonded to wood substrates, improving strength, stiffness, and durability. In addition, screw and nail retention are improved and the wood is protected from moisture absorption and rot. With improved mechanical properties, it is possible to reduce the amount of wood used and/or increase support spans. Plywood, oriented strand board (OSB), and particle board all benefit from Polystrand composite reinforcement. Applications include upholstered furniture frames, shelving, cabinetry, desktops, tables, chairs, and laminated timber.

Table 6 illustrates the level of improvement possible by adding layers of composite reinforcement to various wood substrates.

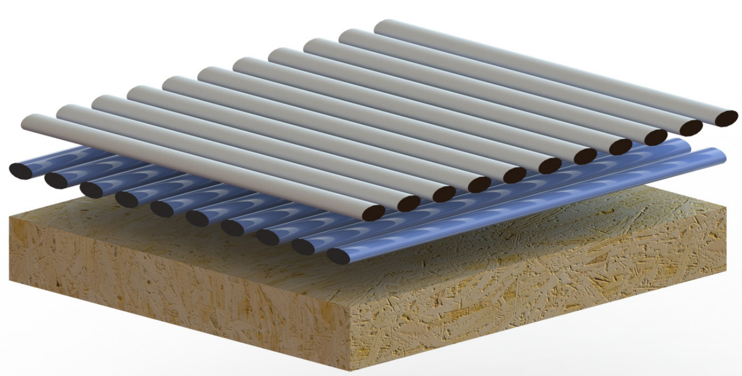
Table 6: Wood Hybrid Performance

Raw Material							Raw Material with Reinforcement			
	Thickness		MOE Wood		MOR Wood		MOE % Increase		MOR % Increase	
	in	cm	psi	GPa	psi	MPa	1 Layer	2 Layer	1 Layer	2 Layer
OSB	0.44	1.12	795,715	5.49	5,954	41.05	18%	41%	20%	41%
OSB	0.75	1.91	637,232	4.39	3,298	22.74	6%	21%	31%	45%
Plywood	0.50	1.27	1.193,028	8.23	8,349	57.56	15%	–	49%	–
Plywood	0.75	1.91	1,077,293	7.43	5,911	40.75	15%	–	92%	–
Plywood	1.10	2.79	1.137.345	7.84	9,261	63.85	6%	16%	32%	54%
Particle Board	0.75	1.91	489,113	3.37	2,161	14.90	40%	66%	194%	250%

Table 7 includes suggested lamination conditions for bonding Polystrand tapes and laminates with wood substrates. Best adhesion is achieved using polyester-based Polystrand material grades. Conventional hot-melt reactive adhesives can also be used in place of hot-pressing, if desired.

Table 7: Polystrand PET Composite to Wood Lamination Parameters

Setting	Value
Platen Temperature	260°–380°F/127°–193°C
Pressure	50–150 psi/345–1034 kPa
Hold Time	15 seconds–2.5 minutes
Cooling Platen Temperature	50°–100°F/10°–38°C
Cooling Time	10–30 seconds



METAL HYBRIDS

Adding Polystrand composite materials to thin gauge sheet metal significantly improves dent and puncture resistance, reduces sound and vibration, and provides an insulating layer. Figure 12 illustrates the improvement of dent resistance that can be achieved by incorporating one and two layers of reinforcement.

Applications include doors, appliances, automotive, and window framing. Benefits include added durability, enhanced performance in hurricane environments, energy efficiency, and lighter weight.

Figure 12: Aluminum Hybrid Dent Reduction

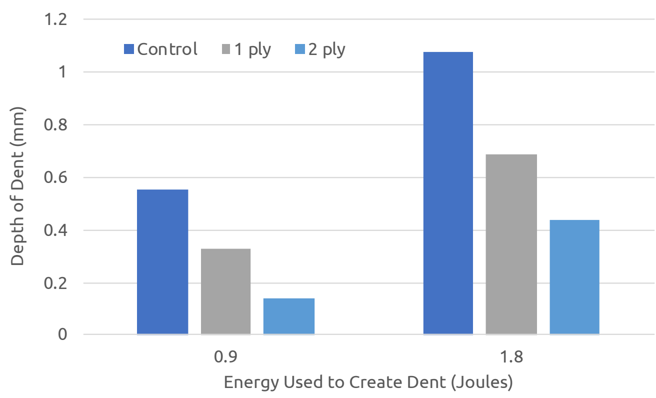
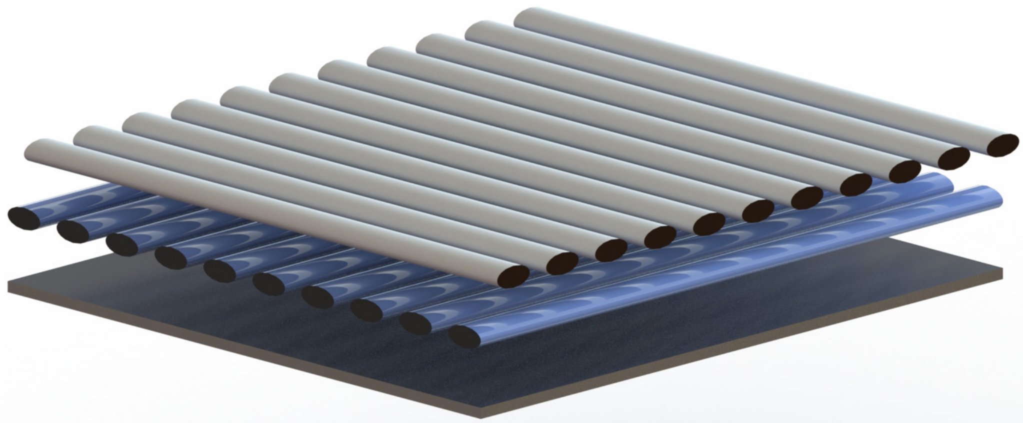


Table 8 offers suggested lamination conditions for bonding Polystrand tapes and laminates with metal substrates. While the lamination process is similar, the inherent heat resistance of metal enables higher processing temperatures and faster processing time compared to wood; cooling times are also reduced because metals conduct heat better than wood. Conditions noted apply to PET-based composites.

Table 8: Polystrand PET Composite to Metal Lamination Parameters

Setting	Value
Platen Temperature	340°–450°F/171°–232°C
Pressure	50–150 psi/345–1034 kPa
Hold Time	5–30 seconds
Cooling Platen Temperature	50°–100°F/10°–38°C
Cooling Time	5–20 seconds



Adhesive Bonding

Various adhesives can be used with Polystrand continuous fiber reinforced thermoplastic composites, the selection of which depends on the base resin system. Break strength achieved in testing is shown in Tables 9, 10, and 11. For detailed adhesive testing results and application-specific recommendations, please contact Avient.

Table 9: PET-based Composite Laminates - Recommended Adhesives

Description	Manufacturer	Average Break Strength	
		psi	kPa
Urethane	Lord	2280–1535	15,720–10,583
Methacrylate	AccraLock	2210–720	15,237–4964
Acrylic	ITW, 3M, Scott Bader	2170–1870	14,962–12,893
Cyanoacrylate	Gorilla Glue	1885	12,997
Epoxy	Loctite, Gorilla Glue	505–340	3482–2344

Table 10: PA6-based Composite Laminates - Recommended Adhesives

Description	Manufacturer	Average Break Strength	
		psi	kPa
Urethane	Lord	1700–780	11,721–5378
Methacrylate	AccraLock	1640–1030	11,307–7102
Cyanoacrylate	Gorilla Glue	1400	9653
Epoxy	Loctite, Gorilla Glue	915	6309
Acrylic	ITW, 3M, Lord	870–780	5998–5378

Table 11: PP-based Composite Laminates - Recommended Adhesives

Description	Manufacturer	Average Break Strength	
		psi	kPa
Cyanoacrylate	Gorilla Glue	1600	11,032
Acrylic	PolyFuse, Scott Bader, 3M	1350–1100	9308–7584
Urethane	Lord	700–560	4826–3861
Epoxy	Gorilla Glue	500	3447

Brands identified are owned by the manufacturers of the adhesive products.

To learn more about Polystrand Continuous Fiber Reinforced Thermoplastic Composites, please contact us at +1.844.4AVIENT.

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