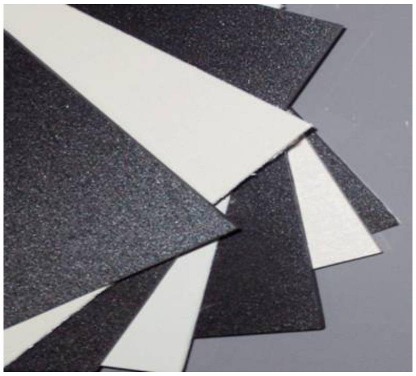
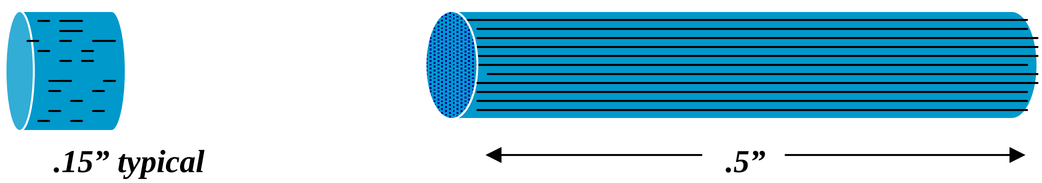


Pennite™ LGF reinforced composite sheet

Penn Fibre is now offering long glass fiber (LGF) reinforced sheet for thermoforming. This product creates the potential to make thermoformed parts with far better properties then parts formed from short glass fiber (SGF) reinforced resins.

Figure 1, Standard SGF resin compound pellet vs. LGF pellet



Pellets produced through the pultrusion process have glass fiber lengths that are typically 25 times longer then conventional short glass reinforced compounds. It has been well documented how much this improves the properties of the material in terms of strength, stiffness, creep resistance and impact.

Forces in reinforced parts are transmitted through the plastic to the reinforcing fibers through shear. The strength improvement is related to the adhesion of the resin to the fibers, the surface area of the fiber, and the shear strength of the resin. It has been determined that for most thermoplastics increasing the length of the fiber improves properties dramatically until fibers are around 3-4 mm (.11-.15”) in length, an then further increases in length deliver diminishing returns in property improvement. In figure 2 length divided/fiber diameter clearly shows this effect for stiffness (modulus).

To produce long glass composites these long pellets are fed directly to the extruder and melt processed into sheet. During the melting step it is well known that in the process of melting the screw shear does break some of these fibers into shorter length, but the average length is still substantially longer then the .02” average seen in short glass fiber (SGF) products.

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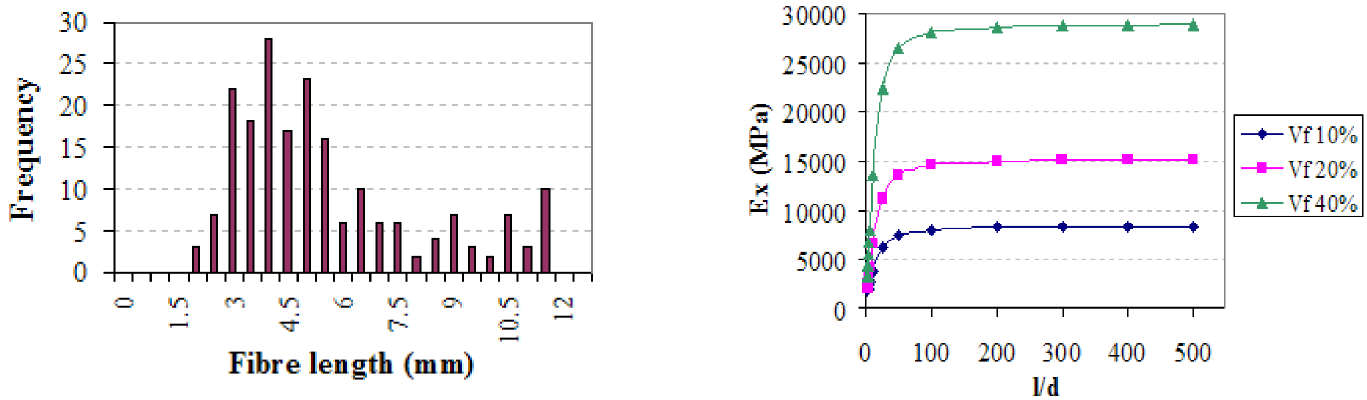
Figure 2 Typical fiber length in parts molded from LFG resin starting with 12.8 mm glass length, and length of fiber/fiber diameter vs. modulus. Vf is volume fraction of glass. Fiber diameter is .017 mm.



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In addition to length effects one must also consider fiber orientation effects. Fibers tend to orient in any melt process in the direction of flow. It is especially notable in thinner parts. The data below in Figure 3 on LFG polyolefin is measured on injection molded samples and is compared to properties of SGF polyolefin. It should be noted that the glass is oriented in the direction of flow. However it is apparent the biggest improvement is in strength, impact and high temperature stiffness (HDT). Additionally LGF products demonstrate improved dimensional stability and creep resistance.

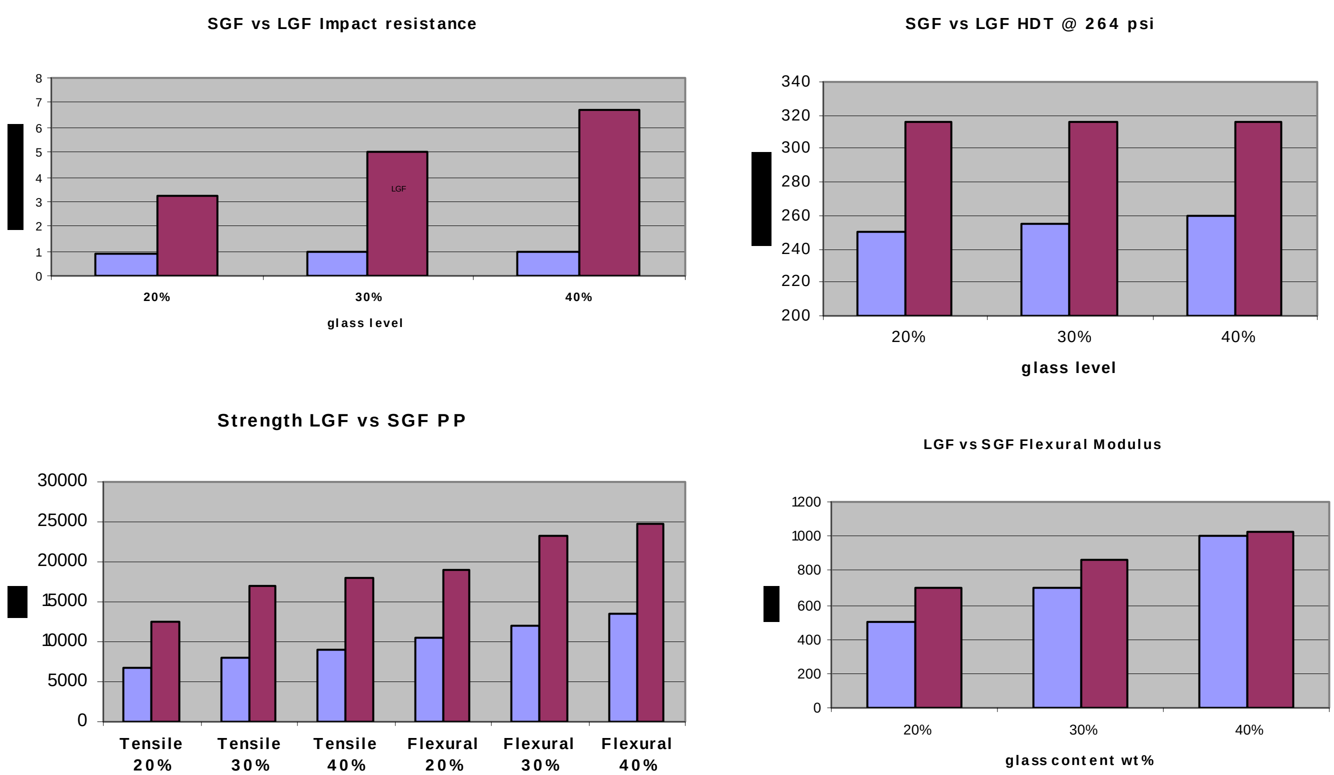

Figure 3 Physical properties of LGF PP vs. SGF PP

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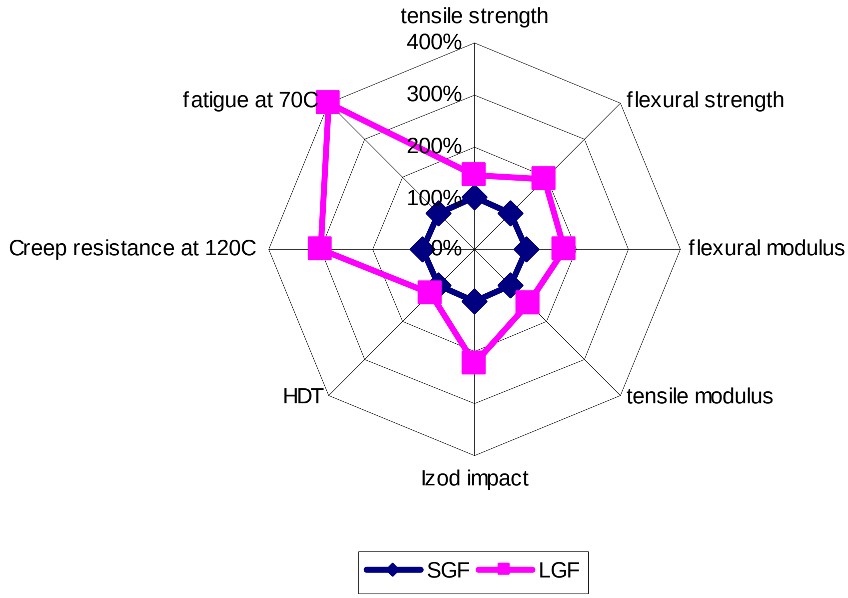
In Figure 4 In figure 4 the overall properties of LGF are shown vs. SGF products. Note that these differences do depend on orientation and the material being considered. But these are indicative of what one can expect when using LGF instead of SGF reinforcement.

Note that one of the biggest benefits in thermoforming vs. injection molding is the lack of knit lines. When long glass fiber melt fronts meet in injection molded parts, the glass does cross from on melt front to the other, and thus the strength across the knit line is typically ~4000 psi, or just the strength of the PP base resin. In the case of a thermoformed parts there are no knit lines where this occurs, and thus the parts do not show this effect.

Figure 4 properties of 40% LGF Polyolefin composite sheet compared to SGF polyolefin



So what applications should be considered for thermoforming LFG composites?

The thermoforming process, by its nature, has much higher scrap rates then what is typically found with injection molding. First there are yield losses in extrusion (maybe 15-20% without regrind), and then again in the thermoforming process (largely dependent on part geometry) that can range from an additional 20-50%. However, on the plus side thermoforming typically has far lower tooling costs (may 5-10% of injection molding) and lower investment cost for the machine, especially for very large parts where the press size requirements go up at a rate of 2-5 tons per square inch of the parts projected area. Hence a breakeven cost for the two processes can be calculated as follows:

Δ Tooling costs— (Δ Yield costs X material price/pt + Δ Process costs/pt) X # parts amortized = 0

In figure 5 the approximate break even costs are plotted for materials by resin price vs. the number of parts over which tooling is to be amortized. For lower cost of materials, the BE may be tens of thousands of pieces. For expensive materials the BE number drops exponentially. For instance a material like PEEK may break even with injection molding at less then 1000 pieces. For a product like long glass Fiber PP the breakeven occurs at perhaps 8-12K parts. This number however is very dependent

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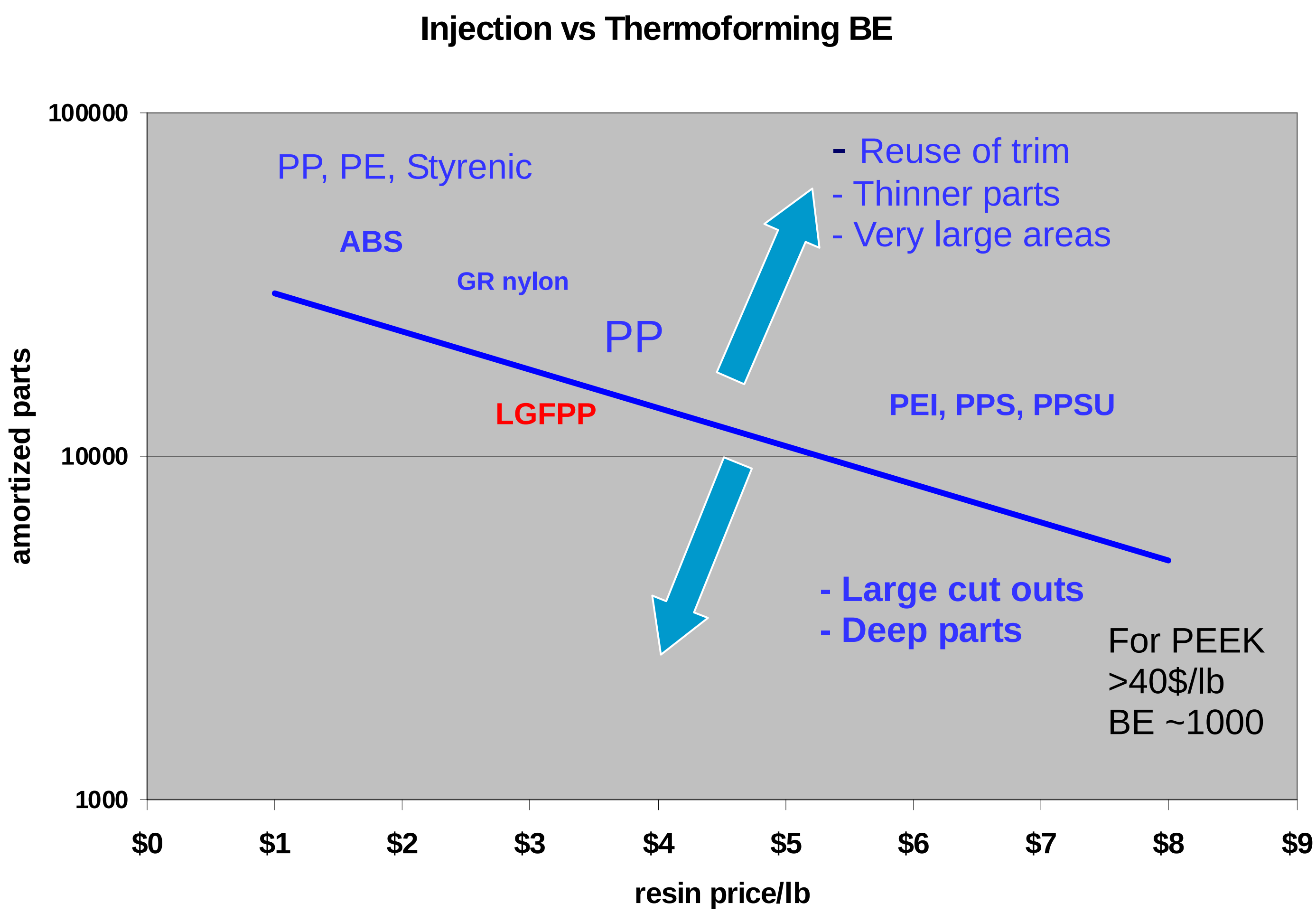
Figure 5. Approximate break even point for injection molding vs. Thermoforming



on part geometry, and whether regrind may be consumed back into the extrusion process. For long glass fiber regrind can not be used without further fiber length degradation.

The commercial applications shown below are injection molded today because of the part production volumes. In many cases thermoforming could be used for prototyping these parts, but will rarely be competitive with an injection molded part.

Automotive battery trays have been molded for years in LGFPP due the excellent creep resistance vs. SGF. Thermoforming is rarely efficient for automotive production volumes, but could be considered for the same applications in off road construction equipment, heavy truck and bus, mobile homes, marine applications, aircraft, motorcycles, farm equipment, or low volume automotive builds.

An office furniture chair may be too high in volume for thermoforming but could be very close to the breakeven point. LGF PP is used in automotive seat backs and again could fit in truck and bus, transit (trains) or marine for virtually the same application.

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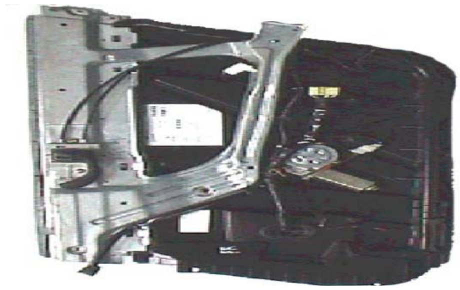
While not suitable for end use packaging, it may have good economics for reusable inter or intra plant packaging and/or dunnage applications. Point of purchase display use could be another area where similar translations could be of interest.



Fender support **Door module** **Instrument panel substrate**

While these LFG parts are all injection molded automotive components, is should be noted that the same applications exist in large truck and bus, aircraft, rail and marine applications. These markets all have build rates that may make thermoforming a more logical process of choice. Limited production cars could also have volumes that cross into the range where thermoforming can compete.

Safety shoe toe caps are commercial in injection molded LGF PP. While footwear application are far too high in volume to consider for thermoforming application such as custom fit orthotics (ie arch supports) or external orthopedic supports (ie knee braces etc.) could be good fits for this kind of material. They are lighter in weight then any other formable materials with this stiffness.

Industrial fan blade applications where the volumes are relatively low can take advantage of the composite's creep, fatigue and stiffness properties. Injection molded Long Glass fiber PP blades are actually commercial today in helicopter tail rotor blades.

Sheets self adhere

One interesting feature of these sheets is the ability to adhere to themselves or other PP substrates. At thermoforming temperatures, the surfaces of the sheet are actually above the melting point of the base resin. Simply laying sheets on top of one another will cause them to laminate during thermoforming. They will also adhere to PP foam or PP fabrics to modify surface characteristics.

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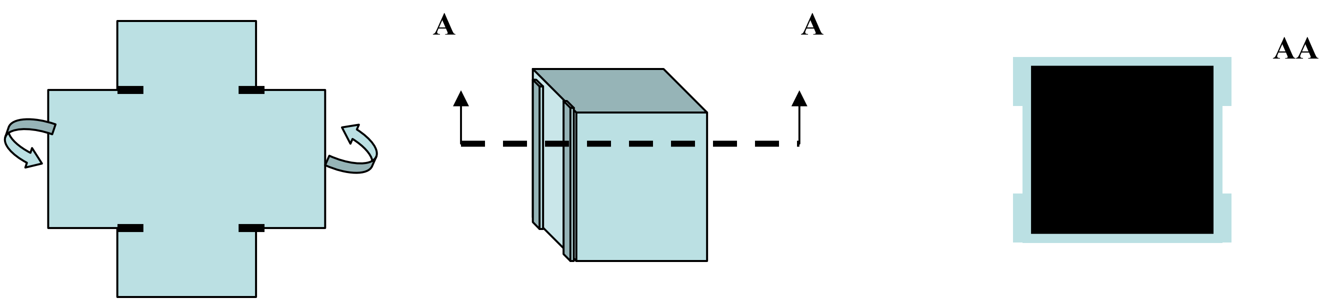
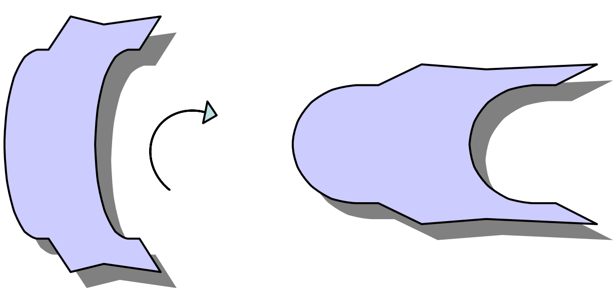
While there is no glass crossing the lamination interface, the sheets are very well bonded and will have shear strength comparable to the unreinforced polymer. As this is generally the neutral plane of a part in bending, there is little stress across the interface. This allows the designer to strategically thicken selective sections of the part .

Bonding to itself makes it very suitable for twin sheet thermoforming such as the process used to make the ductwork shown at left. Here two sheets are bonded at the edges and vacuumed open akin to blow molding. It should be recognized that the strength across this knit line is again no stronger then straight neat resin at best.



Using this feature allows for folding sheet into a desired geometry and then overlapping the surfaces such as in the figures above and the examples below. This hinge would have a theoretical break strength of up to 9000 pounds (2” wide X .25” thick X 18,000 psi tensile) .



Hinge with up to 18 Kpsi tensile Strength

Pipe hanger with up to 1MM psi flex modulus and 316 ^{o}F HDT

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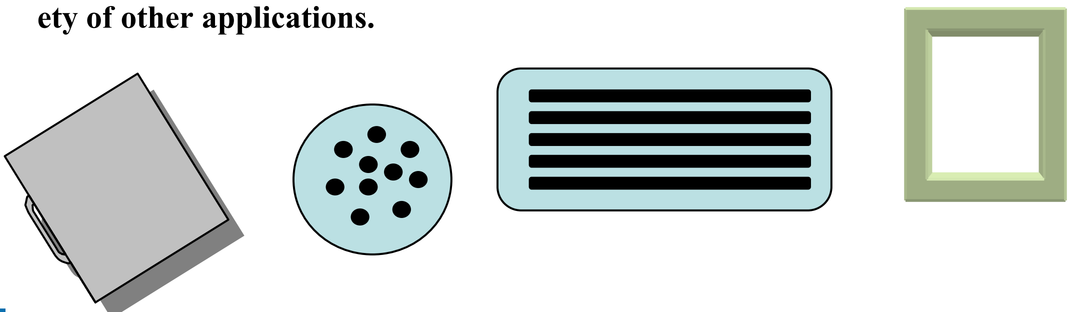
Back pack frames have converted over the years from metal to plastic due to flexibility and strength vs. weight. Some use products as such as polyethylene and others may use very high performance composites. LGF thermo formable composite sheet strikes a midpoint being 3 or 4 times stiffer then PE, but far less costly that continuous fiber layups.

In marine applications the products may fit in hatch covers, seating, window (port) surrounds, paddle blades, scuppers, covers, instrument clusters, wind generator fan blades, companion way hatch covers, line separators, bumper hangers, life line connectors, thru hull strainers, vent, and a variety of other applications.



Fans
Fan shrouds
Fascias
Fascia supports
Ground effect panels
Fender supports
Bumper beams
Instrument panels
Cab panels/tops
Door modules
Window surrounds
Vents
Load floors
Battery housings
Seat backs

Want to know more?

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