Advances in High Fiber Composites

By

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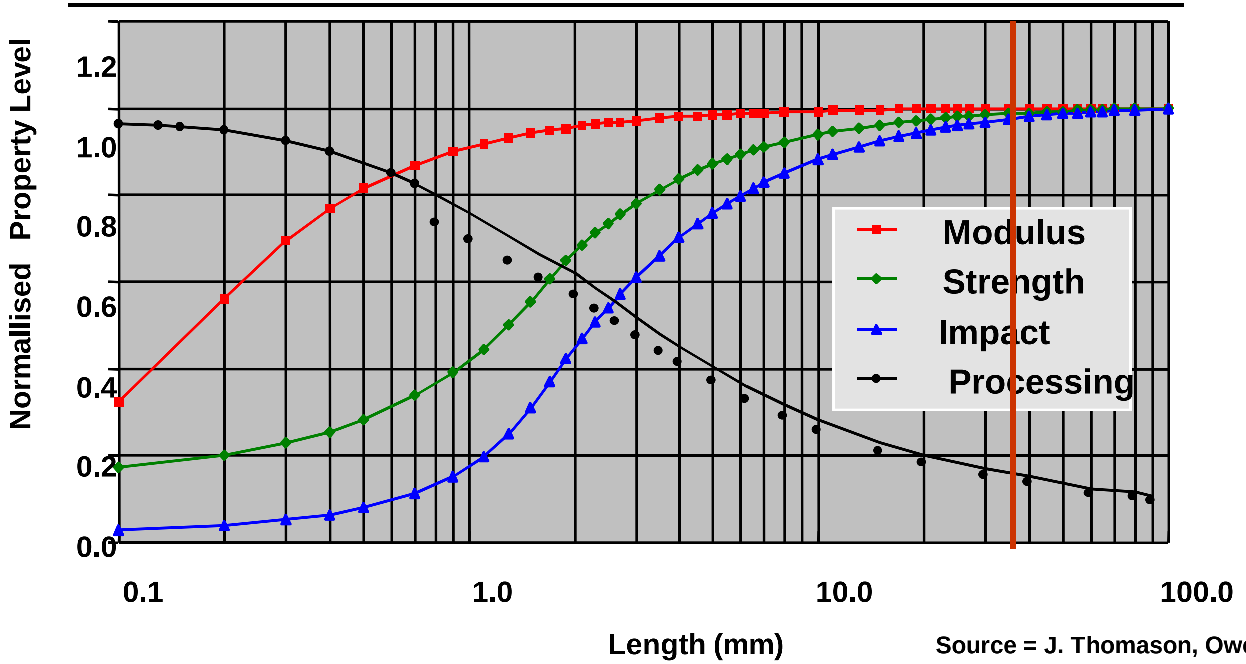
2008 SPE "Automotive Composite Conference & Expo," Troy, MI USA

What is stimulating the development of High Glass Fiber (HGF) Composites?

- With the rapidly escalating costs of resins, “fillers,” especially fibers, can reduce material costs and improve structural performance
- There is an increased demand for higher performance, light weight “structural” composites (mass reduction, improved durability,
- With Carbon Fiber at high market prices ($/lb), the use of lower cost fibers (E Glass) is desirable, if higher performance can be achieved
- The use of newer material processing technologies is allowing for better fiber “wet out” with traditional polymer resins
- Mass reduction in automotive applications using higher performance composites is becoming more desirable

Long Fiber Performance

Composite Properties vs. Glass Fiber Length



Source = J. Thomason, Owens Corning

PP+30% GF 14 micron DUCS, Uncoupled PP

Longer Fiber Lengths Offer Enhanced Properties

What is new with Highly Fiber Filled Composites?

Definition: High fiber filled composites – composite matrixes with > 55% fiber fill.

There are new developments in highly fiber filled composites. This presentation will cover:

- Polyurethane Pultrusion Composites
- Continuous Fiber Thermoplastic Composites

Polyurethane Pultruded Composites

The use of Thermoset Epoxies and Polyesters for pultruded profiles has been limited to ~ 55% fiber filled composites. Polyurethane resins now have been successfully used in pultruded processes where up to 80% fiber filled composites have been achieved. In addition to highly filled PU profiles, increased pultruded line speeds have also been achieved. Other PU pultrusion benefits are:

- Improved component "toughness (impact, creep/fatigue) and stiffness"
- Ability to replace mat with direct draw rovings (cost benefit)
- PU offers very good chemical resistance to automotive fluids (oils, ethylene glycol, brake fluids, gasoline)
- Better retention of screws (mechanical fasteners) embedded in HGF PU
- Less hydrolyzed potential over longer time periods (better property retention)
- Thinner & stronger profile components mean lower mass & costs

Mechanical properties of Long Fiber (> 12 mm) Composites

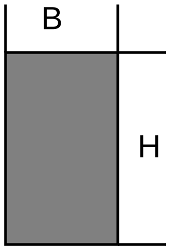
Property	Units	40% PP GMT	55% GF Polyester	80% GF Polyurethane
Process		Compression	Compression	Pultrusion
Resin Type		PP	vinyl ester SMC	Thermoset PU
FG Type	E Glass	continuous random FG	chopped random FG	continuous uni FG
Density (SG)	gr/cm**3	1.22	1.91	1.97
Flex Modulus	psi	892,000	2,490,000	6,900,000
Flex Strength	psi	23,200	69,000	180,000
Tensile Strength	psi	15,700	47,000	80,000

Note: GMT & SMC material properties from Matweb.com

PU properties from Bayer Material Sciences

Stiffness/Mass Comparisons – Box Beams

	Steel	Aluminum	HGF PU
E =	30,000,000	11,000,000	6,900,000
SG =	7.8	2.7	1.97
Density =	0.281 lbs/in**3	0.097 lbs/in**3	0.071 lbs/in**3



I = (BH**3)/12

Stiffness = EI

In order to obtain the same stiffness, EI(steel) = EI(Alum) = EI(PU)

Assume for Steel: B = H = 1.0; then for Aluminum & HGF PU

$H_{(alum)}$ = 1.396 & $H_{(HGF\ PU)}$ = 1.631

Mass of each section:

Steel = 1*1* 0.281 = 0.281 lbs

Alum = 1 * 1.396 * 0.097 = 0.135 lbs

HGF PU = 1* 1.631 * 0.071 = 0.116 lbs

Mass Reduction for HGF PU:

Vs. Steel = 59%

Vs. Alum = 15%

Natural Frequencies – Steel vs. Aluminum vs. HGF PU

The natural frequency, f_n, of an automotive component plays an important role in the response to harmonic loads and long term behavior of the component. Generally, the higher the natural frequency, the better the behavior of the component. The natural frequency is defined by **k/m**, where **k** is the spring stiffness and **m** is the mass.

Normalizing the f_n for steel, we can compare the frequencies for Aluminum & HGF PU -

f_n (Alum) = 1.37 f_n (Steel)

f_n (HGF PU) = 1.43 f_n (Steel)

The lower modulus, but much lighter weight composites have higher natural frequencies and better harmonic response than steel components.

Potential High Strength PU Applications

Automotive:
- Beams
- Drive shafts
- IP cross member
- Load Floors
- Flat Springs
- Stabilizer Bars
- Seat Frames

Non Auto:
- Wind turbine Shafts & Blades
- Composite Pipe
- Sporting Equipment
- Architectural Moldings
- Window Lineals

Continuous Fiber Thermoplastic Composites

Historically, the development of FG filled long fiber & continuous fiber thermoplastic composites has been limited to ~ 50% fiber fill. New developments in direct fiber fill extrusions have lead to fill rates of up to 80%. The high glass TP Composite “tapes” can then be assembled various thickness and fiber orientation sheet stock. The advantages of these materials are:

- Improved resin “wet out” can produce near class A smooth surfaces

- Higher strength, thinner sheet stock can be used to make structural laminates with low mass core thermoplastics *foam & honeycombs”

- The use of high strength fibers – carbon, KEVLAR, Basalt – can produce ultra high strength panels, i.e. – high impact ballistic applications

- The use of “thin” HGF TP tapes can enable thermoplastic filament wound process & applications that have lighter mass and costs vs. thermoset composites

Mechanical Properties of Long Fiber (> 12 mm) Composites

Property	Units	40% PP GMT	42% Uni PP GMT	70% 0-90 GF PP
Process		Compression	Compression	Compression
Resin Type		PP	PP	PP
FG Type	E Glass	continuous random FG	continuous uni FG	0-90 FG (5 layer)
Density (SG)	gr/cm**3	1.22	1.25	1.65
Flex Modulus	psi	892,000	1,310,000	1,800,000
Flex Strength	psi	23,200	39,200	50,000
Tensile Strength	psi	15,700	39,200	46,000

Note: GMT material properties from Matweb.com

0-90 GF/PP properties from Crane Composites

High Fiber Thermoplastics: Laminated "Sandwich" Panels

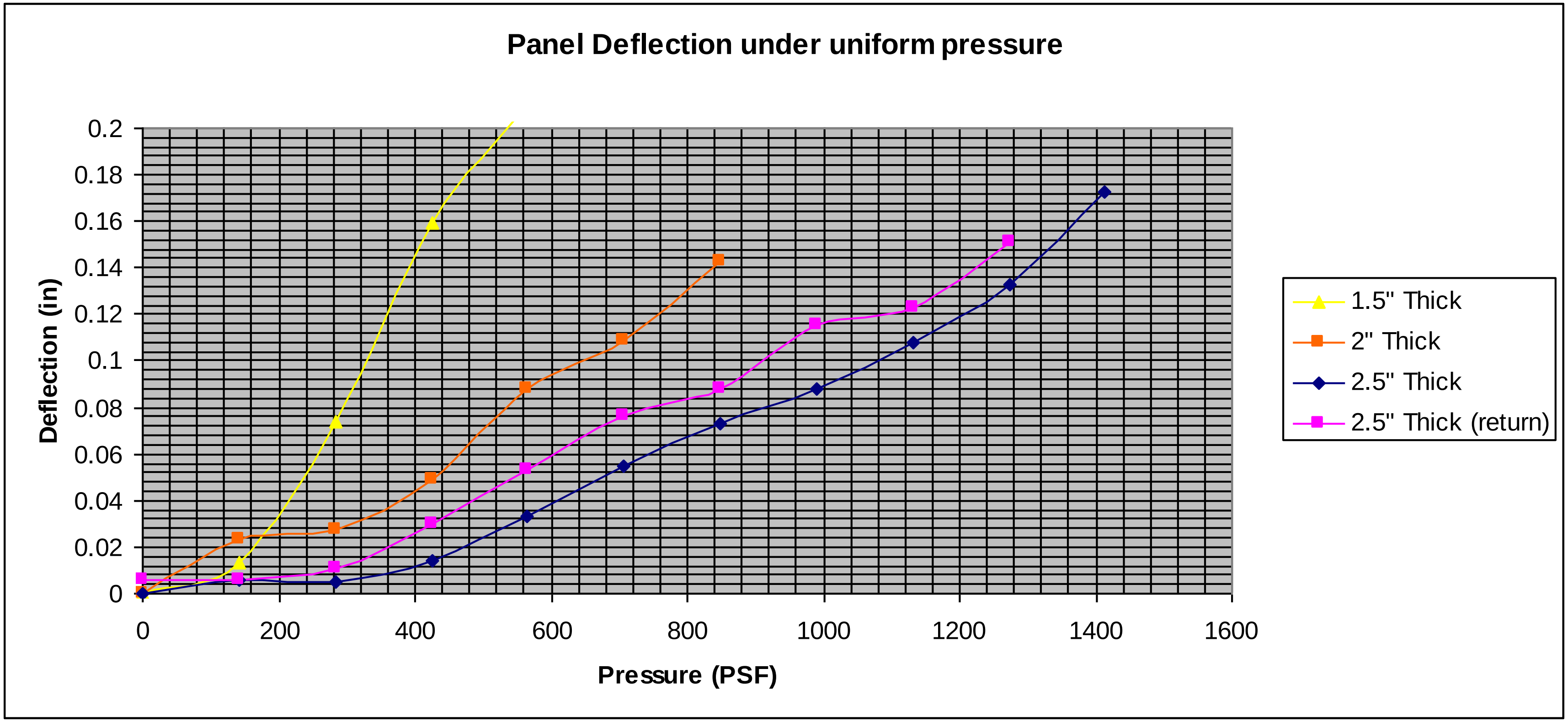
Combination of high fiber TP "skins" and low density cores to form a "Sandwich" Laminate

- **Engineered materials – high strength & tough skin on outer layers; low density "thicker" core – produces high material & section modulus**
- **High shear layer between skins & core GMT's gives structural laminate performance**

"Sandwich" Laminate – (60 to 75% FG/PP composites laminated together)

New Materials – HGF TP "Sandwich" Panels

HGF Skin/Foam Core Sandwich panels – subject to uniform pressure loads



Courtesy of Fulcrum Composites, Midland, MI

HGF TP Applications

Automotive:
- Load Floors
- TP Reinforcements
- IP cross members
- Seat Back Panels
- Flat Springs
- Horizontal Body Panels

Non Auto:
- Wind turbine Blades
- Composite Pipe
- Sporting Equipment
- Architectural Moldings
- Laminated Floor/Wall Pane