ADDITIVE MANUFACTURING OF INNOVATIVE NEAR NET SHAPE CONTINUOUS FIBER THERMOPLASTIC COMPOSITE PREFORMS

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OVERVIEW

1. Thermoplastic composite program jointly carried out by:
   - Coats North America
   - University of Alabama at Birmingham (UAB)

2. Introducing Coats' Synergex™ and Lattice™ Technology

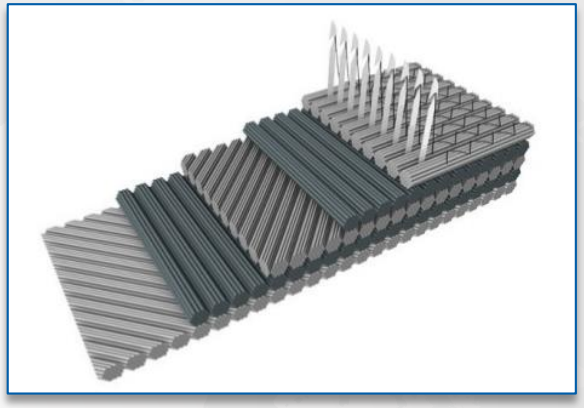
3. Design Studies – Leaf Spring and Front end module

4. Results of testing comparing panels molded using Synergex™/ Lattice™ Preforms and Thermoplastic composites in UD Tapes and Organosheet.

5. Conclusion: Near net shape thermoplastic preforms with similar mechanical properties and greater flexibility in fiber orientation as compared to alternative thermoplastic composite product formats.

THERMOPLASTIC COMPOSITE PREPREG

1 RAW MATERIAL TOW



2 FABRIC WITH PRESET LAYER ORIENTATION

3 THERMOPLASTIC PREPREG PROCESS

4 PATTERN CUTOUTS

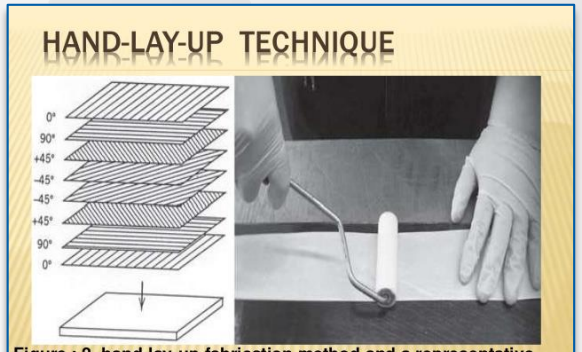


Figure : 2 hand-lay-up fabrication method and a representative lay-up sequence. Individual layers can be cut by hand or by a computerized machine cutter. The layers can be stacked one on top of the other by hand or by a robot.

5 PREFORM VIA STACKING OF PLIES/LAYERS BY MANUAL OR ROBOTIC PROCESS

SYNERGEX™/LATTICE™

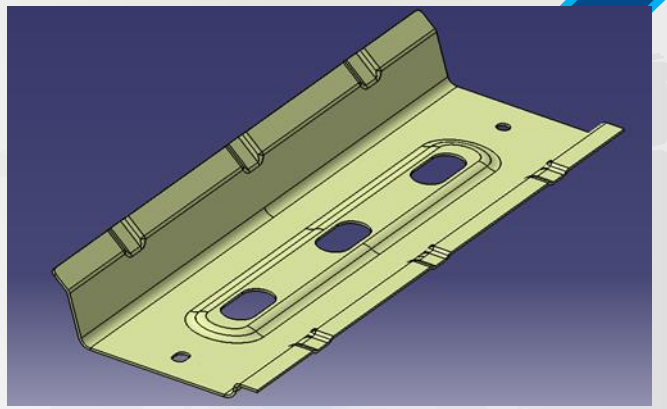
1

Raw material tow & Thermoplastic Fiber

2

Comingling Process

3D CAD - Part



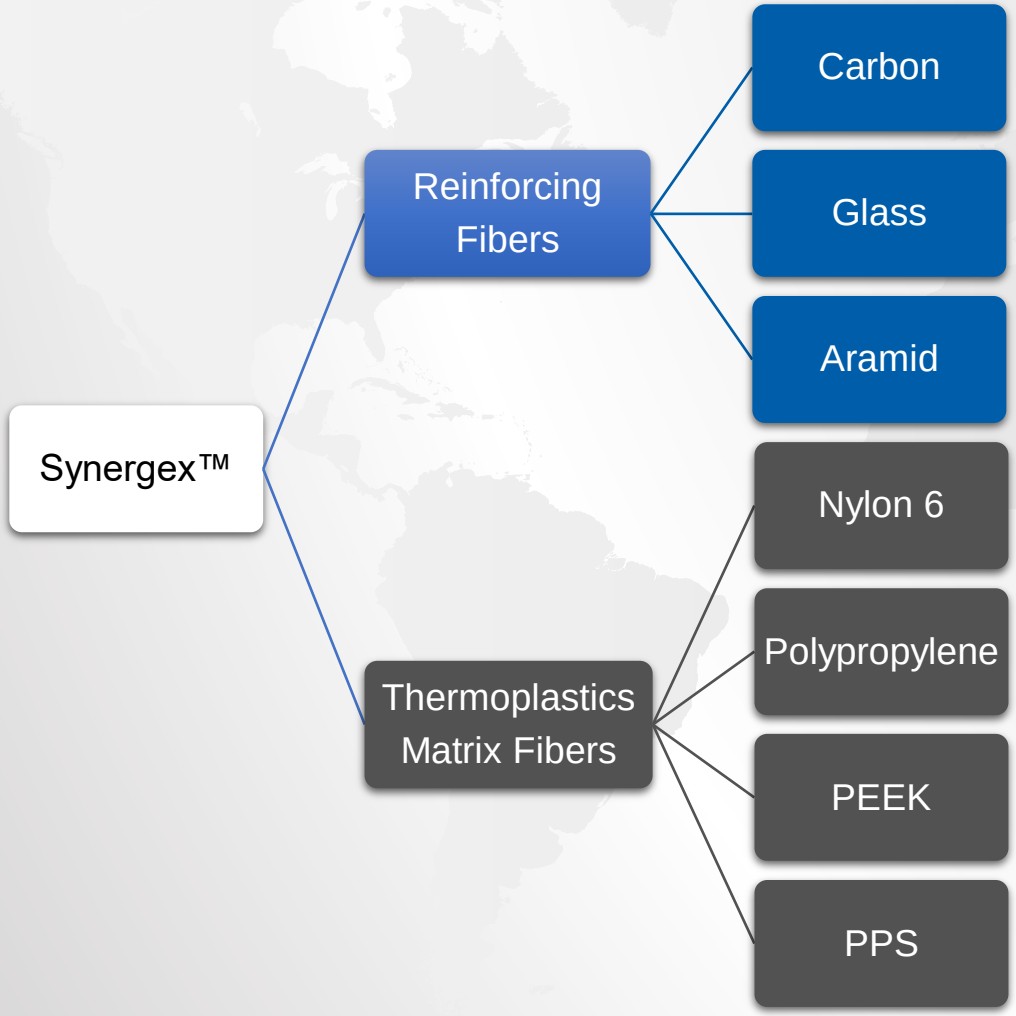
Optimized design for fiber orientation and layer composition

2D Lattice™ CAD

3 Automated additive manufacturing

- Reduced waste
- Reduced labor
- Reduced cost

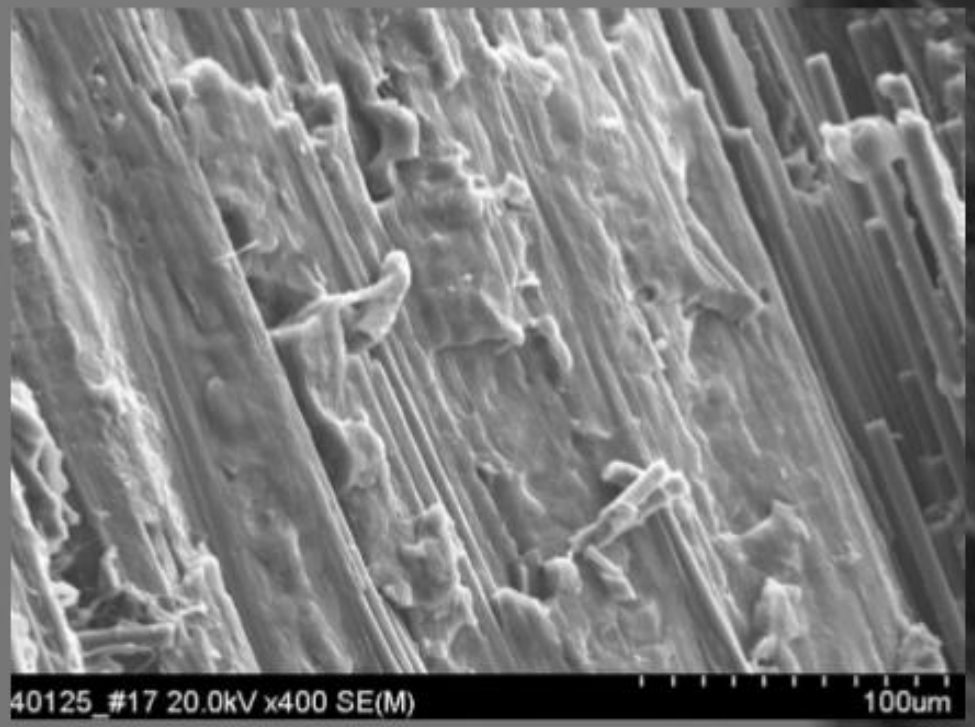
COMMINGLED FIBERS - SYNERGEX™



- Commingled fibers
- Typically 2 fibers commingled in one final product
- Fiber content adjusted based on denier of input raw material
- Compression Molding
  - Made with thermoplastic fibers
- Overmolding
  - Overmold composite form with reinforced injection molding compounds

COMMINGLING RESULTS

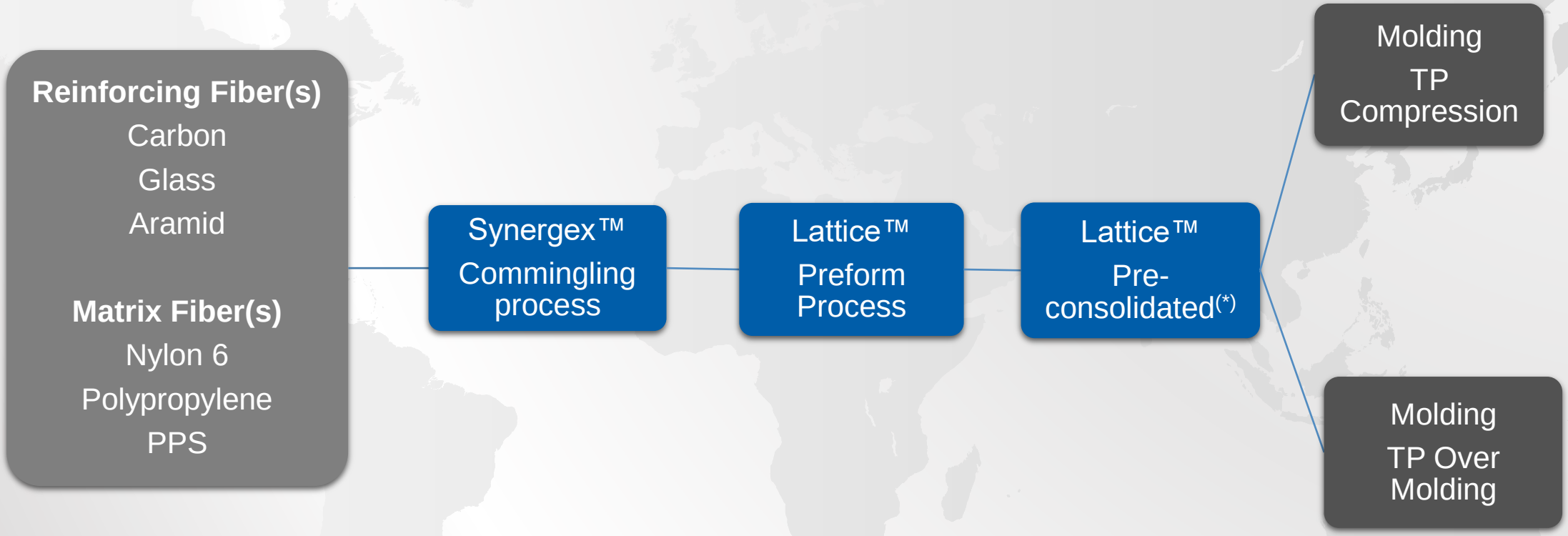
Synergex™ Commingling Technology



Synergex™ (Carbon Fiber-Nylon) SEM Scans

- SEM – Scanning Electron Microscopy scan of tested sample
- Shows excellent fiber wetting
- Superior wet-out of the fiber is what gives higher mechanical properties

TECHNOLOGIES FOR AUTOMOTIVE LIGHT WEIGHTING



Coats provides commingled fiber; converts CAD data to fiber path data & provides near net shape Lattice preforms to molders.
(*) Some customers utilized Lattice Preforms without Pre-consolidation

COMMINGLED FIBERS - SYNERGEX™

Fiber Type		% Fiber Volume Fraction				
Reinforcing	Thermoplastic					
Glass	Nylon 6	62%	55%	45%		
	Polypropylene	65%	60%	55%	48%	45%
	PEEK	56%	45%			
	PPS	57%	52%	48%		
Carbon	Nylon 6	63%	60%	54%	48%	
	Polypropylene	63%	54%	47%		
	PEEK	61%	56%	52%		
	PPS	60%	54%			
Aramid	Nylon 6	61%	54%			
	Polypropylene	57%	54%	52%		
Basalt	Nylon 6	59%	49%			
	Polypropylene	53%				

- Table shows the spectrum of Synergex Commingled Fibers that have been made in Sevier, NC and Bursa, Turkey for various applications
- Not shown in the database is the commingled Carbon-Glass Fibers that have also been prepared for RTM evaluations

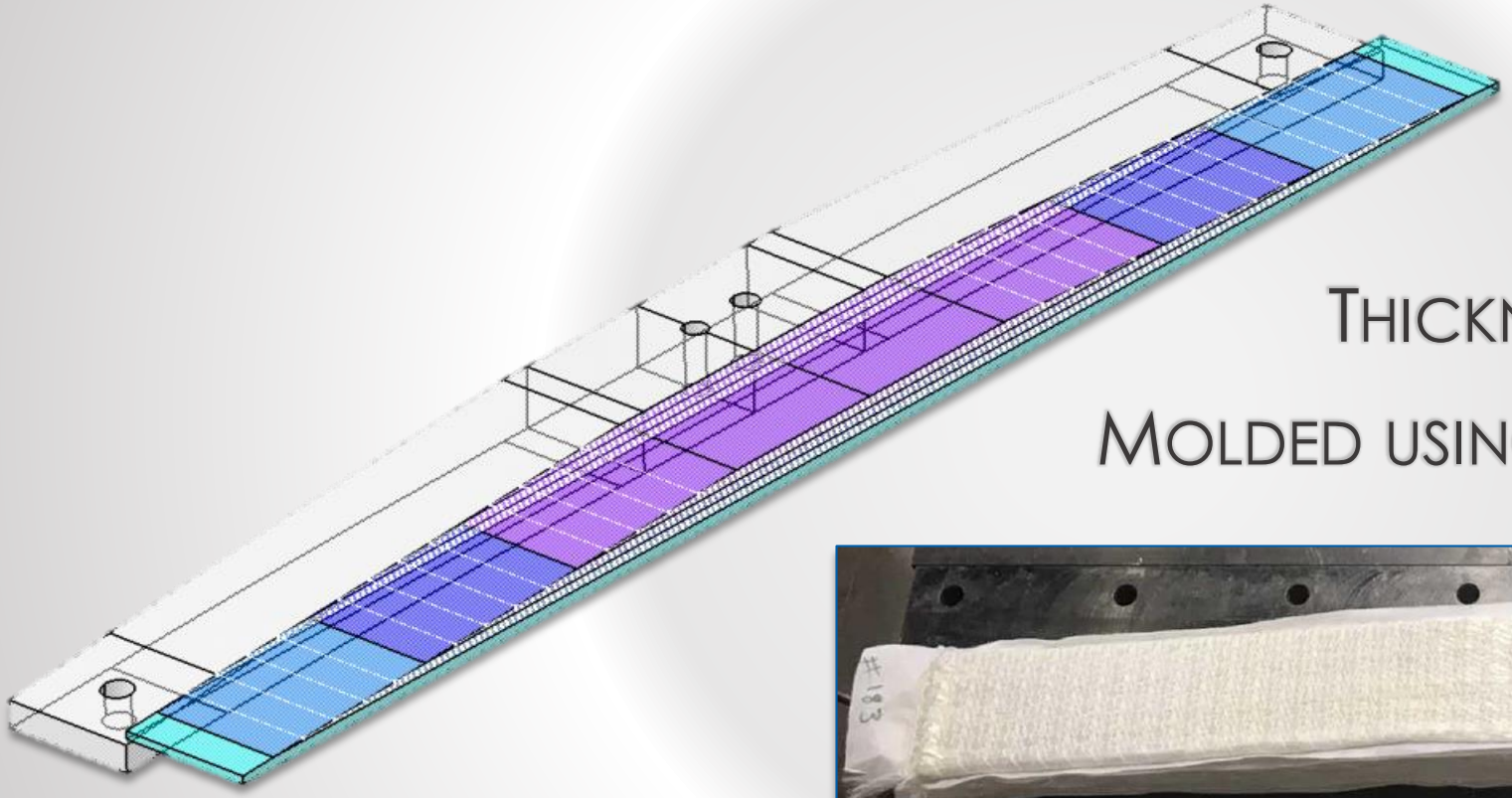
DESIGN STUDIES

CF LATTICE™ VS CONVENTIONAL TECHNOLOGY

	Conventional Technology					Coats Technology	
						CF-Lattice	
	Aluminum	Magnesium	Steel	CF-SMC	GF-SMC	50% of all CF in 0° Direction	90% of all CF in 0° Direction
Tensile Strength, MPa	137	130	215	300	100	650	1150
Tensile Modulus, GPa	69	40	210	35	10	56	96
SPG	2.7	1.74	7.8	1.5	1.85	1.37	1.37
Weight Reduction vs. Aluminum	0.0%	22.7%	-99.4%	12.9%	104.1%	45.6%	54.6%

- Generic design assuming modulus driven thickness/weight.
- Typically SMC uses a 35% safety factor on properties.
- Thickness values on all materials assume a 0% safety factor.
- CF Lattice™ provides the greatest weight reduction material option.

THERMO-PLASTIC LEAF SPRING



TAPERED LEAF SPRING

GLASS/POLYPROPYLENE

THICKNESS FROM .55" TO 1.2"

MOLDED USING 10 LATTICE PREFORMS

GOR APPLICATION REDESIGNED WITH SYNERGEX™

Typical Vehicle GOR

Material	Part Weight (Kg)
Magnesium	2.7
CF Composite / CF PP	2.05
FG Composite / LGPP	2.57

CAE Design Weights of GOR Based on Bending and Torsional Load Cases

COATS SYNERGEX™/LATTICE™

Process:

- Additive Manufacturing
- Automated via Machine Programming
- Flexible Fiber/Thermoplastic Combinations via Comingling
- Optimized solutions for custom fiber orientations and layering

Benefits:

- ✓ Reduced material waste
- ✓ Increased laminate lay-up quality and repeatability
- ✓ Consistent fiber fractions based on denier of inputs
- ✓ Reduced cost & weight of final part

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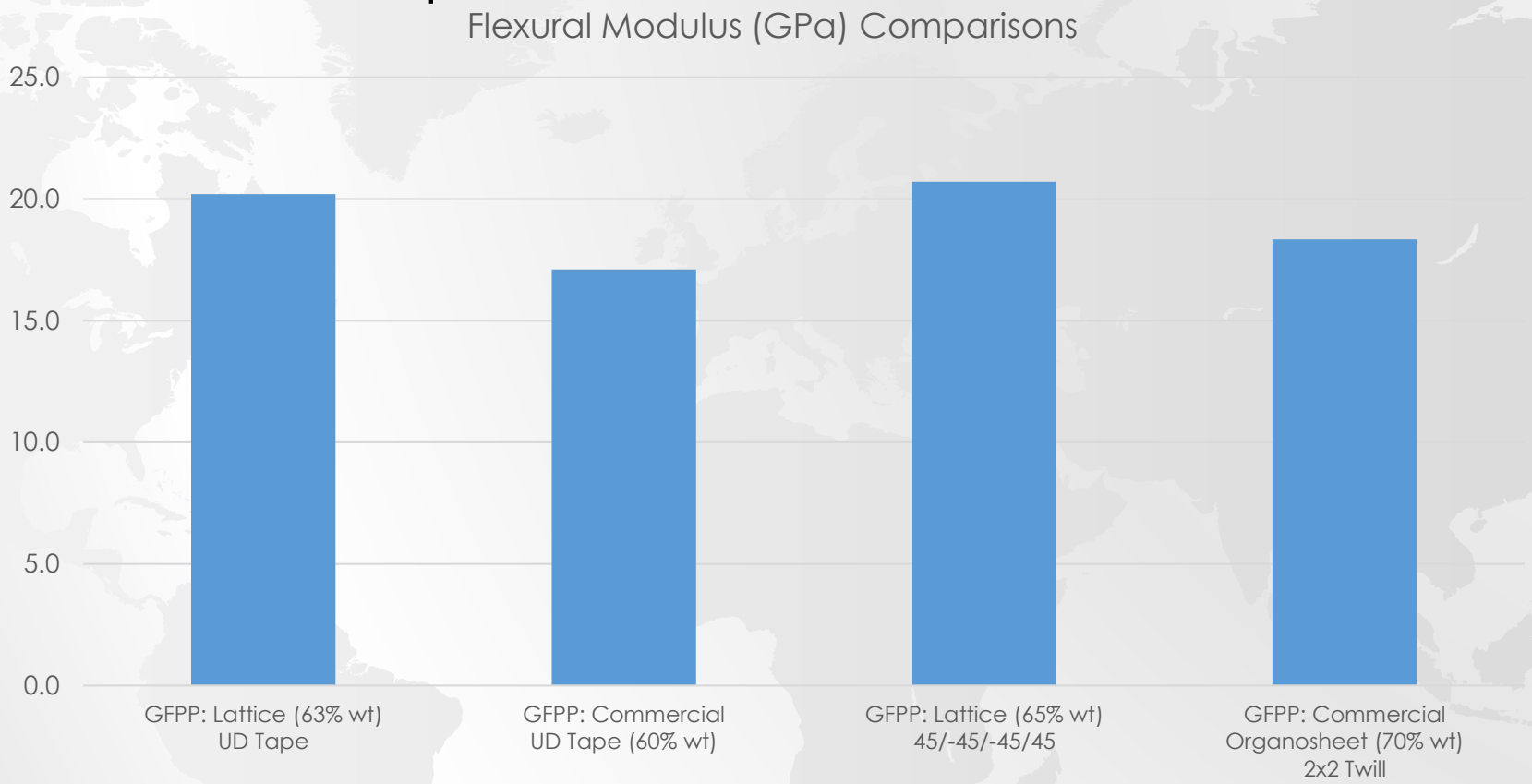
PP-Fiberglass Flexural Properties



- Unidirectional and Organosheet for Lattice and Commercial products for PP/Fiberglass Laminates
- Test Method: ISO 14125
- Data indicates that the Synergex™ /Lattice™ has properties similar to UD Tape and Organosheet

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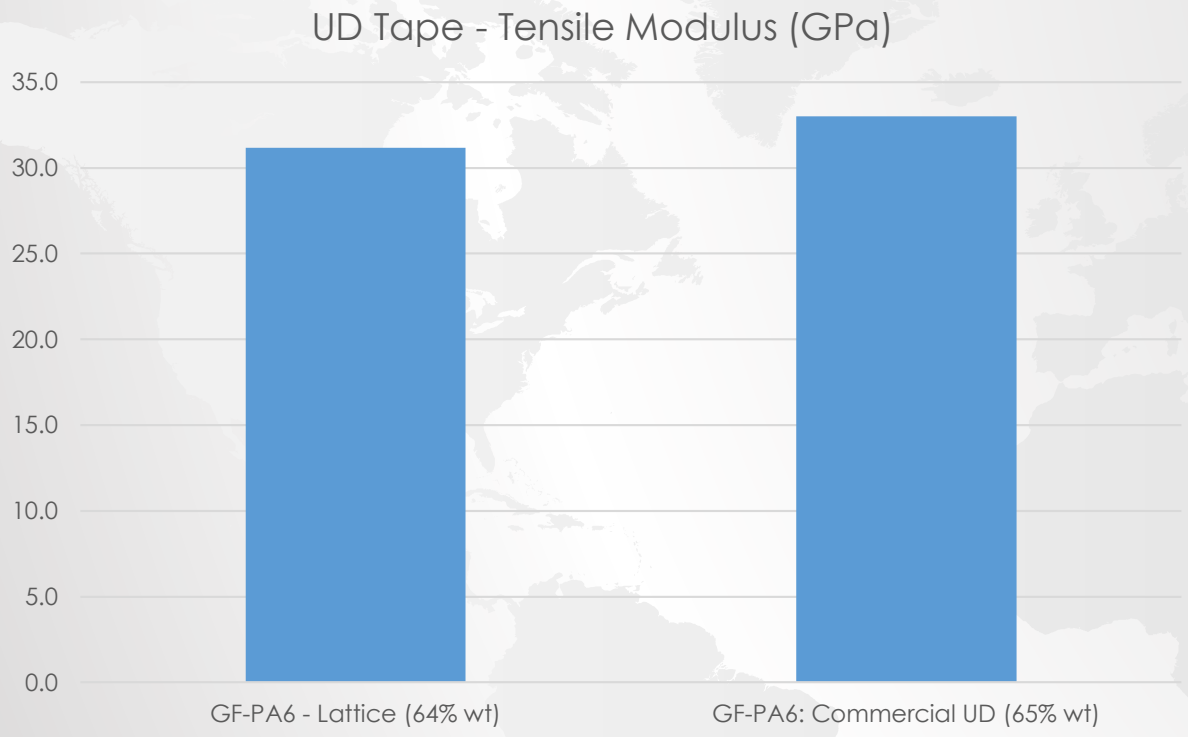
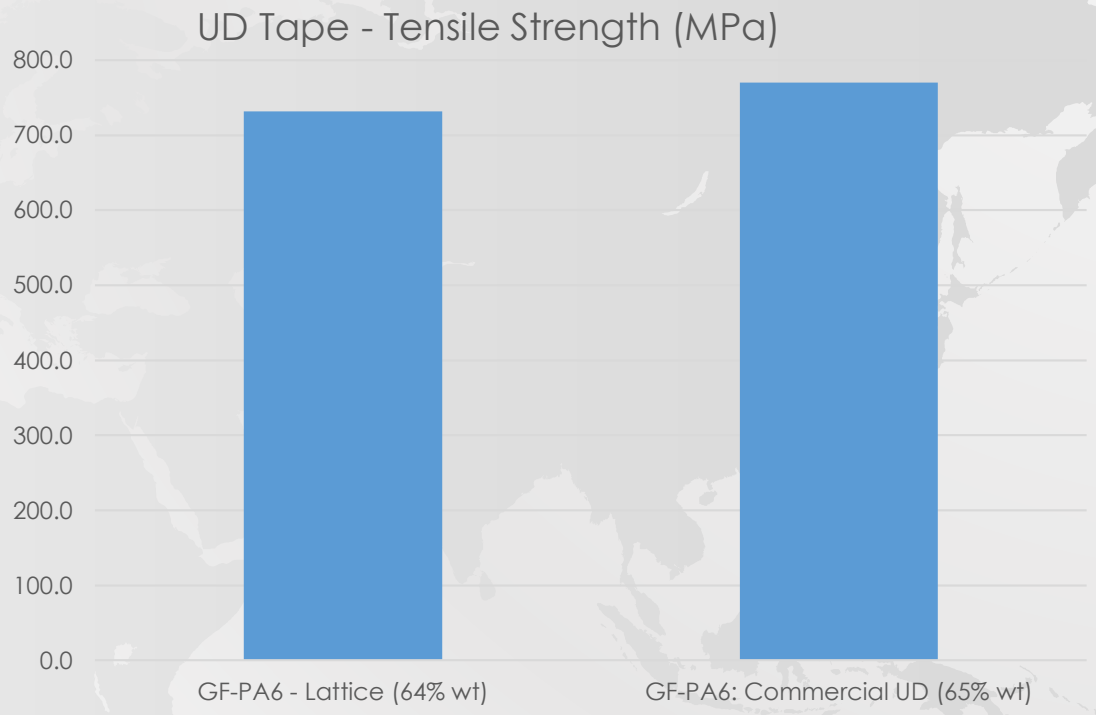
PA6-Fiberglass Tensile Properties

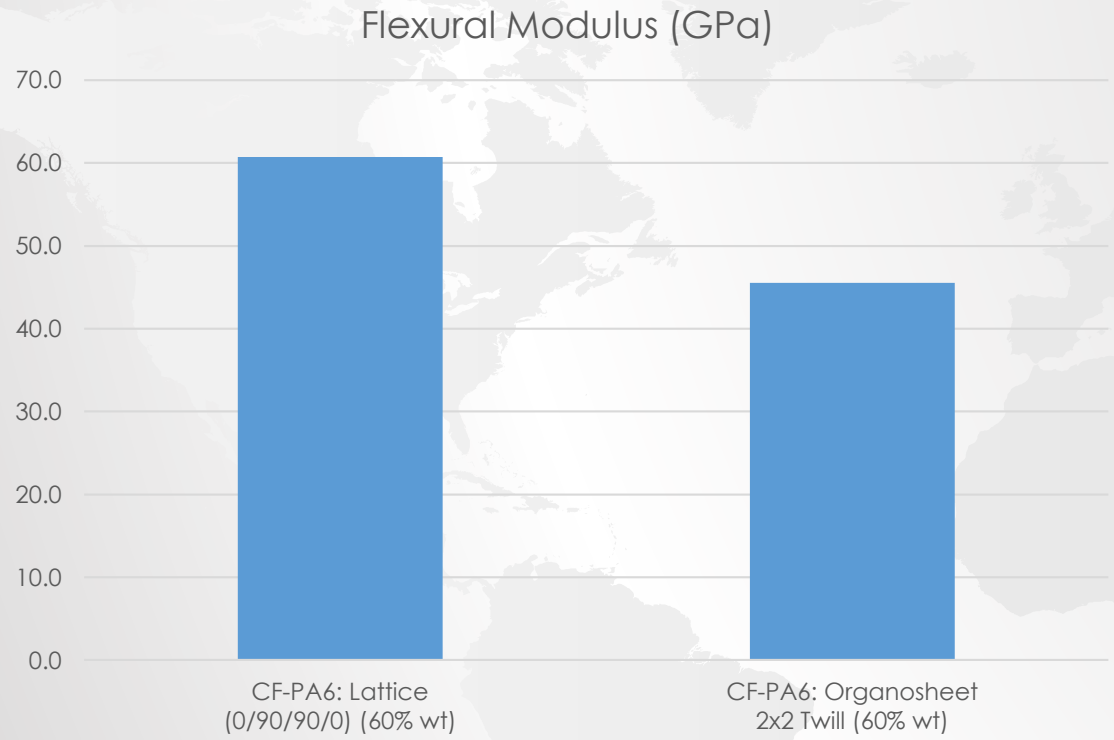


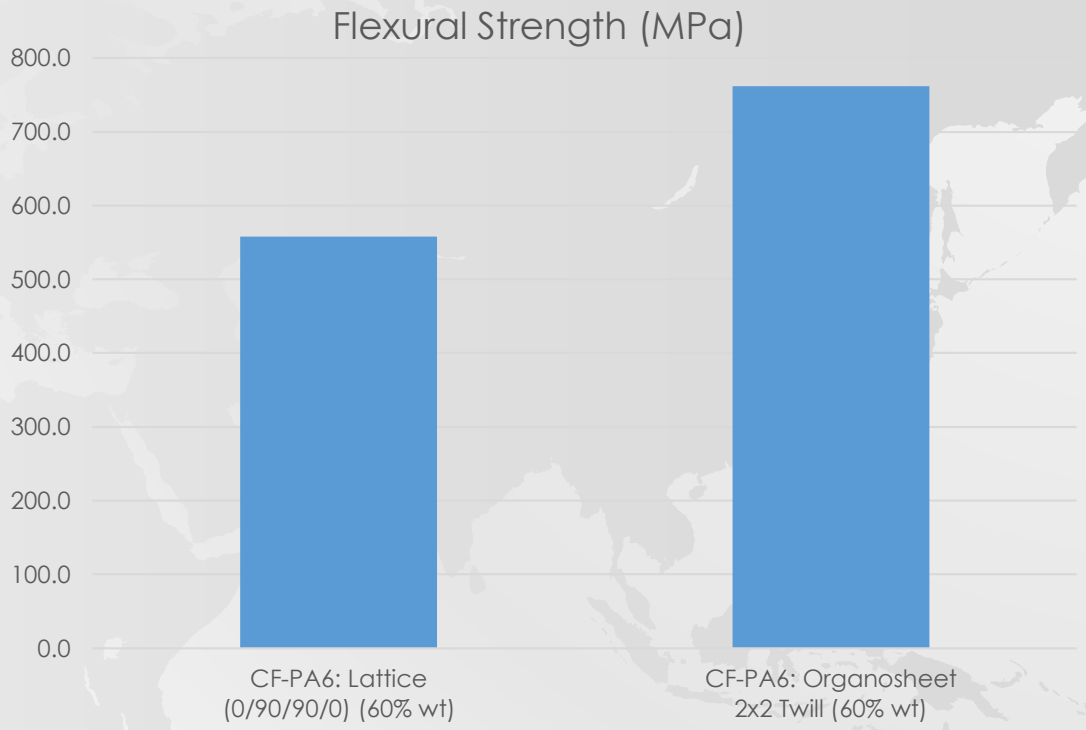


- Unidirectional PA6/CF Laminates for both Lattice and Commercial products
- Test Method: ASTM D3039M
- Data indicates that the Synergex™ /Lattice™ has properties similar to UD Tape

COATS SYNERGEX™/LATTICE™

PA6-Carbon Fiber Flexural Properties





- Lattice (0/90/90/0) and Organosheet (2x2 Twill): PA6/CF Laminates
- Test Method: ISO 14125
- Data indicates that the Synergex™/Lattice™ has properties similar to Organosheet

CONCLUSIONS

- The PP/FG and PP/CF Synergex™/Lattice™ design study showed comparable mass for GORs versus magnesium.
- Synergex™/Lattice™ PP/FG composite had comparable flexural strength and modulus compared with the PP/FG organosheet and UD tape.
- Synergex™/Lattice™ PA6/FG composite had comparable tensile strength and modulus compared with the PA6/FG UD tape.
- Synergex™/Lattice™ PA6/CF composite had comparable flexural strength and modulus compared with the PA6/CF organosheet composite.
- Lattice™ inherently has
  - Better fiber utilization (no wastage) than textile based preforms
  - Process lends itself to faster preform preparation time
- Synergex™/Lattice™ near net shape preforms are a viable alternative for organosheet and UD tape thermoplastic composites.

QUESTIONS?

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THANK YOU