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Vacuum Assisted Resin Transfer Molding (VARTM) for Kenaf Fiber Based Composites

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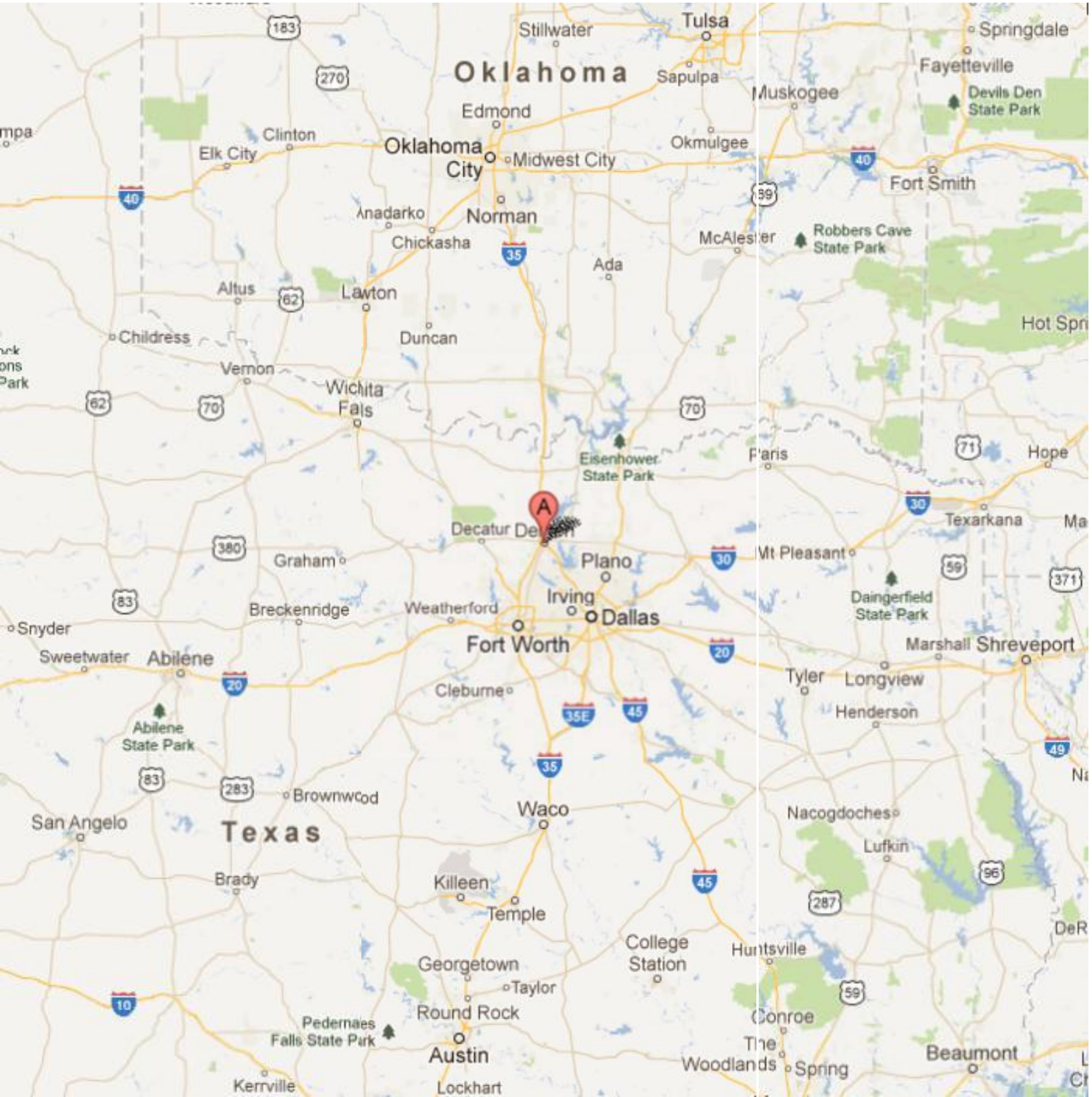


Mechanical and Energy Engineering Department

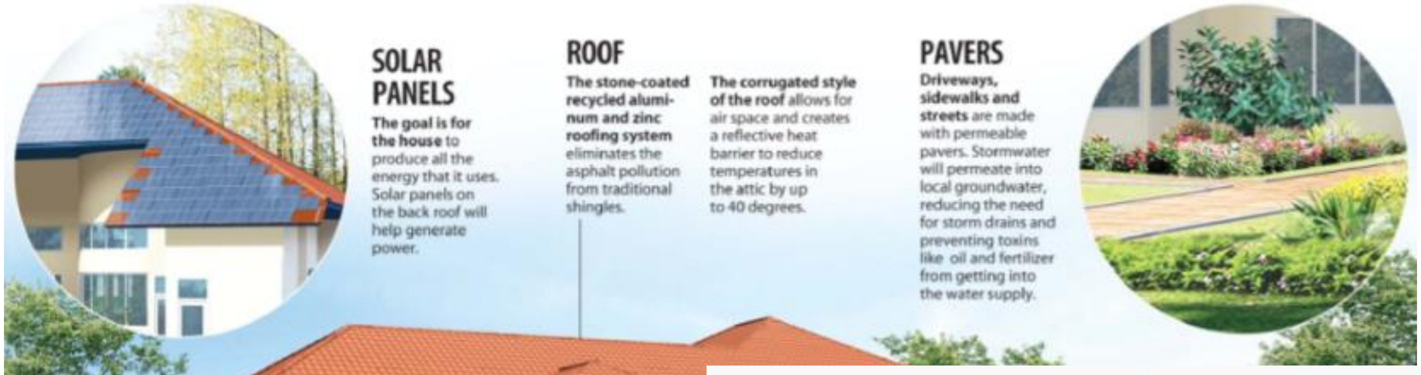
College of Engineering

UNT Discovery Park

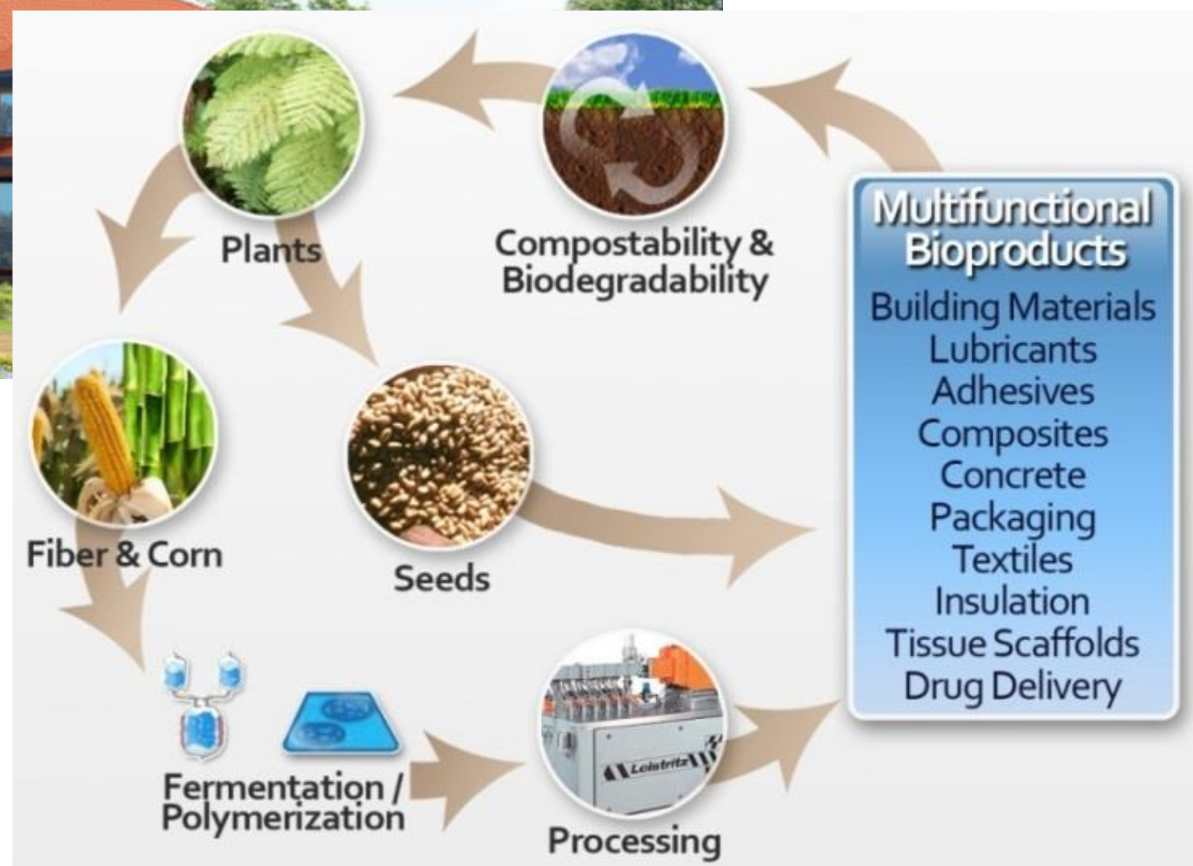
Renewable Bioproducts Research Cluster

Two Research Clusters

Mechanical and Energy Engineering Department at UNT



Renewable Energy and Conservation



Renewable Bioproducts

UNIVERSITY of NORTH TEXAS

Bioproducts Manufacturing Laboratory at UNT Discovery Park

Donations from Huber

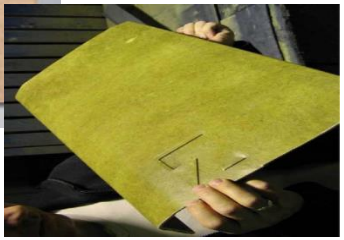
Structural Testing facility at UNT

Full scale truss, shear wall, and long span beam testing capabilities

Natural Fiber Structural Component Designs

Conducted at Mississippi State University

Supported by US DOE: light weight vehicle design



Advantages

- ❖ Light weight
- ❖ Low cost
- ❖ Less reliance on petroleum resource
- ❖ Environmental friendly

Sisal

Bagasse

Bamboo

Kenaf

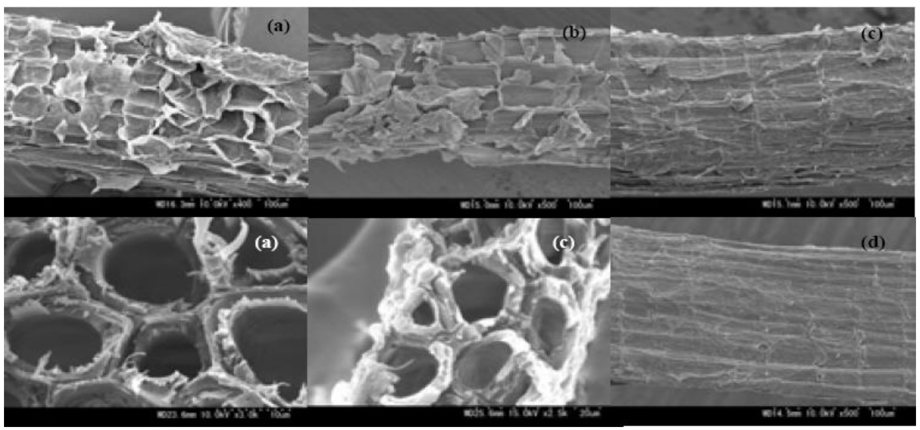
Woody Materials

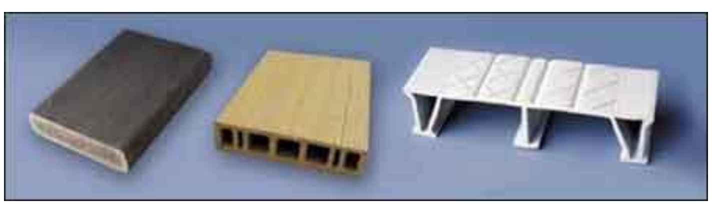
Other Annual Crops

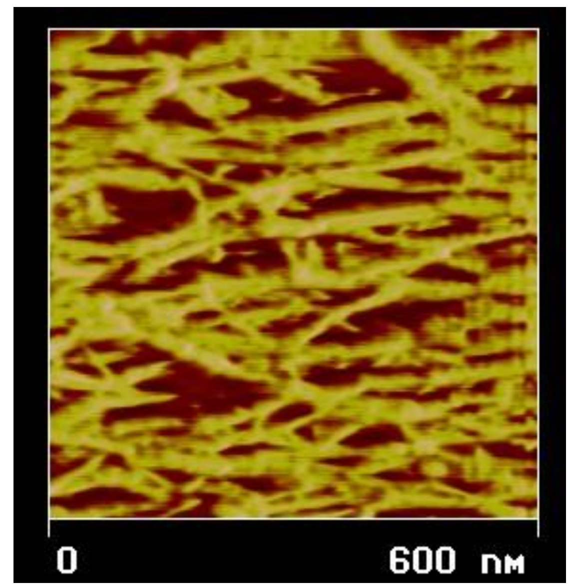
About 50% of vehicle internals are made of polymeric materials. According to the American Plastics Council, the vehicles contain an average of 250 pounds of plastics, which accounts for 12% of their weight.

Manufacturer	Parts	Fiber Source
Chrysler	Door cladding, seatback lining, package shelves, seat bottoms	Flax, hemp, sisal, coconut
Ford	Door trim, trunk liner	Kenaf
Toyota	Door trim	Kenaf
Volvo	Dashboards, ceilings, seat filling, cargo floor tray	Hemp, jute, rapeseed

Natural Fiber Structural Composites: (2) *Air pocket defects in composite products due to the micro pores in the fibers*







AFM Scan

Property Summary of Kenaf Fiber Unsaturated Polyester Composites through Compression Molding Process

Properties	Kenaf/UPE*[1]	Commercial Glass/UPE*[2]
Density, g/cm^3	1.2-1.4	1.9
Flexural Modulus, GPa	7.0-10.0	10.0
Flexural Strength, MPa	70-100	167
Tensile Modulus, GPa	6.0-13.7	10
Tensile Strength, MPa	50-70	74
24 hr WA, %	1.5-6.0	0.7

*[1]Kenaf fiber + $CaCO_3$ content: 60 wt%

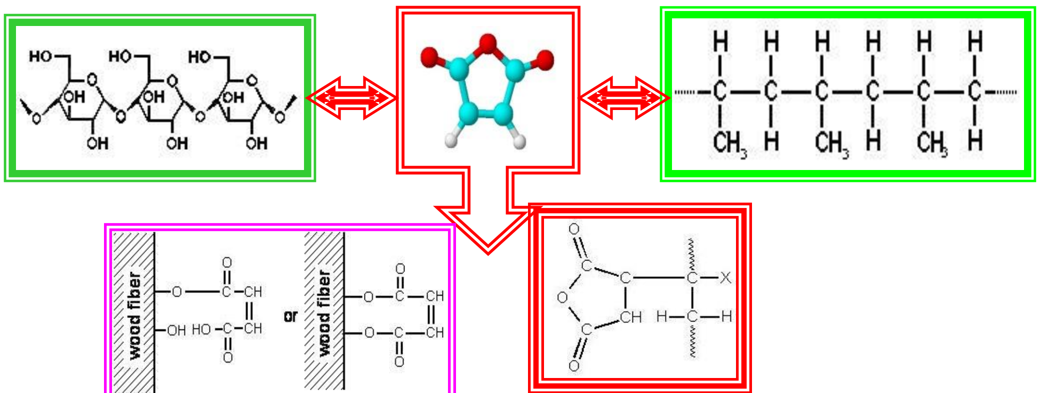
*[2]Glass fiber content: 25%, and $CaCO_3$ content: 40 wt% EpicBlendSMC (Magna Auto)

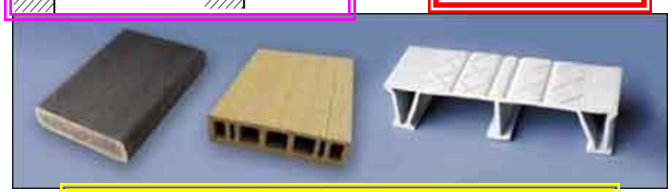
Natural fiber Structural Composites:
(1) *Incompatibility at fiber-polymer interface*

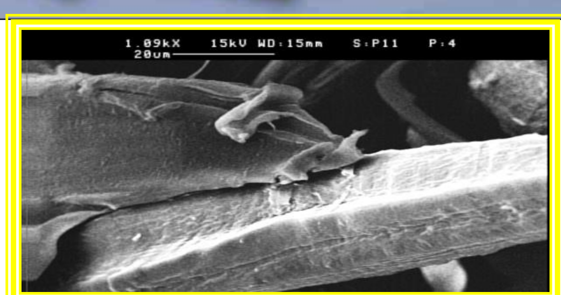
Hydrophilic Natural Fiber

Co-polymer or Monomers

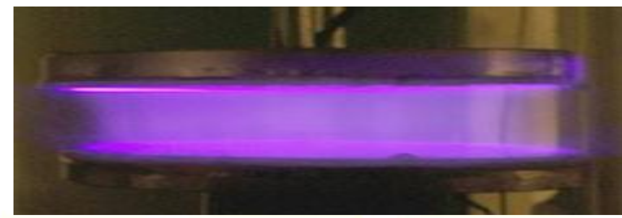
Hydrophobic Polymer Matrix

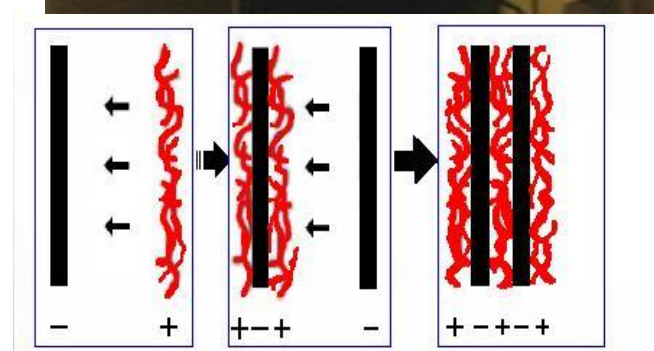


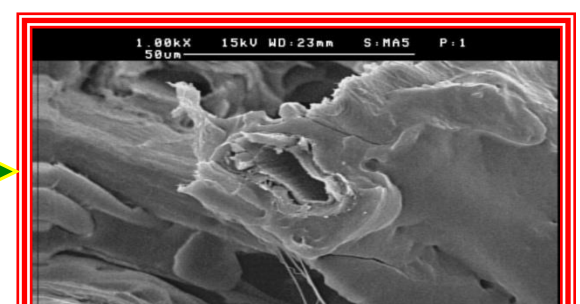




Plasma Treatment







VARIM

There are different names to describe this technique:

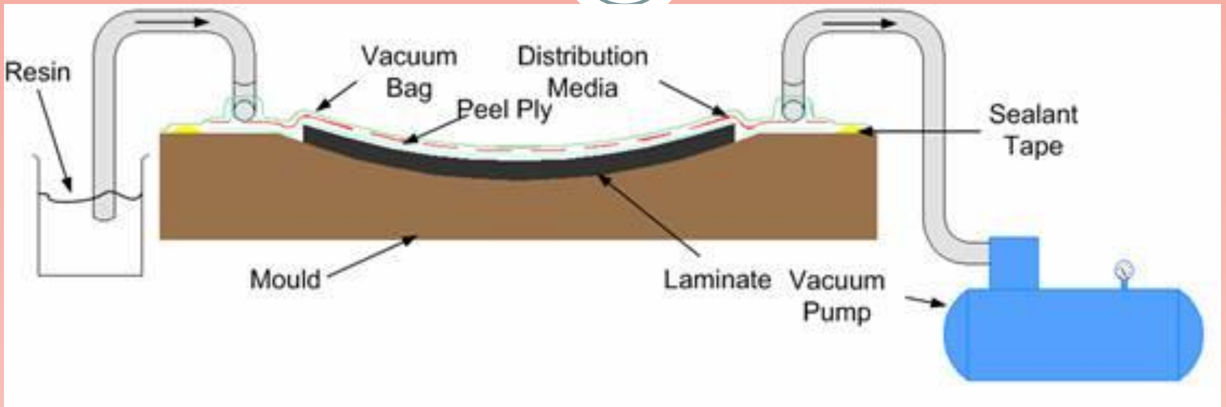
- Vacuum Assisted Resin Infusion Molding **(VARIM)**
- Vacuum Assisted Resin Transfer Molding **(VARTM)**
- Vacuum Assisted Resin Infusion process **(VARI)**
- Vacuum Bag Resin Transfer Moulding **(VBRTM)**
- Seemann Composites Resin Infusion Moulding Process **(SCRIMP)** etc.

However, all of them are basically the same technology, which uses liquid resin infused into dry fabric layers by vacuum pressure.

Typically, VARTM is a three-step process

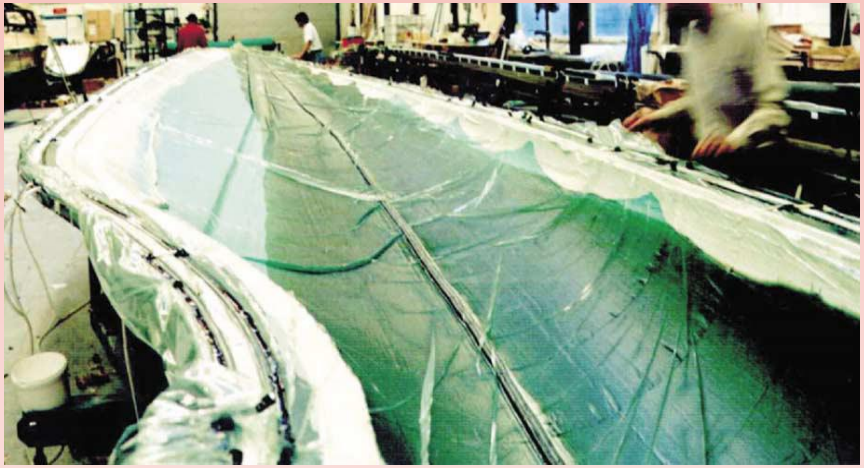
1. reinforcement preform lay-up
2. preform impregnation with resin by vacuum
3. resin curing

Vacuum Assisted Resin Transfer Molding



Boat production: Releasing from the mold

Fiber glass wind blade Halve piece



Objectives

To apply the VARTM process to kenaf fiber structural composites fabrication to reduce the manufacturing defects and maximize the performance potentials

- Improve the interfacial compatibility during the fabrication of kite board material.
- Improve the resin penetration of the porous structure in kenaf fibers

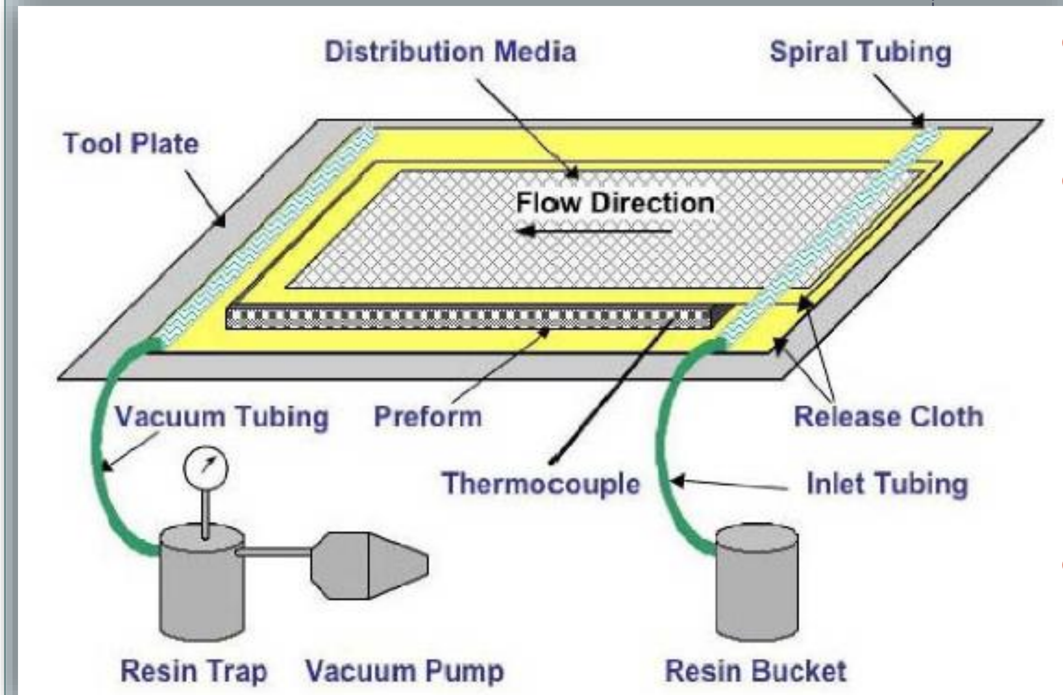
Kenaf

- Member of hibiscus family
- Speculated to have originated in southern Asia or Africa
- Grows quickly, yielding up to 10 tons of dry fiber per acre yearly
- Can be grown in the US
- Produces two types of fibers

VARTM: Kenaf Fiber Preform

- The kenaf fibers were manually formed into a mat 160 mm by 120 mm in size by means of an metal box.
- The mat was pre-pressed at 3 MPa for about 30 min at 50°C.
- Each specimen had 40 g kenaf fibers and about 20 g resins.

VARTM: Resin infusion



Cano, R. J.; Loos, A. C.; Jensen, B. J.; etc. *SAMPE Journal* **2011**, *47*, 50–58.

- A vacuum bag was placed over the mold
- Resin infusion and vacuum tubes were inserted in the bag. A vacuum was created between the mold and the bag
- The resin was infused through infusion tubes. The vacuum pulled the resin along the distribution layer into the fiber reinforcement preform

VARTM: Resin Infusion (continue)

- A vacuum of 1.3-1.6 KPa was applied to the infusion system. The unsaturated polyester was infused into the preform at 50°C. It took about 40 min for applying the vacuum and transferring the resins.

VARTM: Resin Curing

- The resin curing occurred in the hot-press with a pressure of 13 MPa. The resin-infused preforms were pre-cured at 100°C for 2 h, and then post-cured at 150°C for 2 h.
- Once the resin cured, the VARTM bag and distribution layer were removed

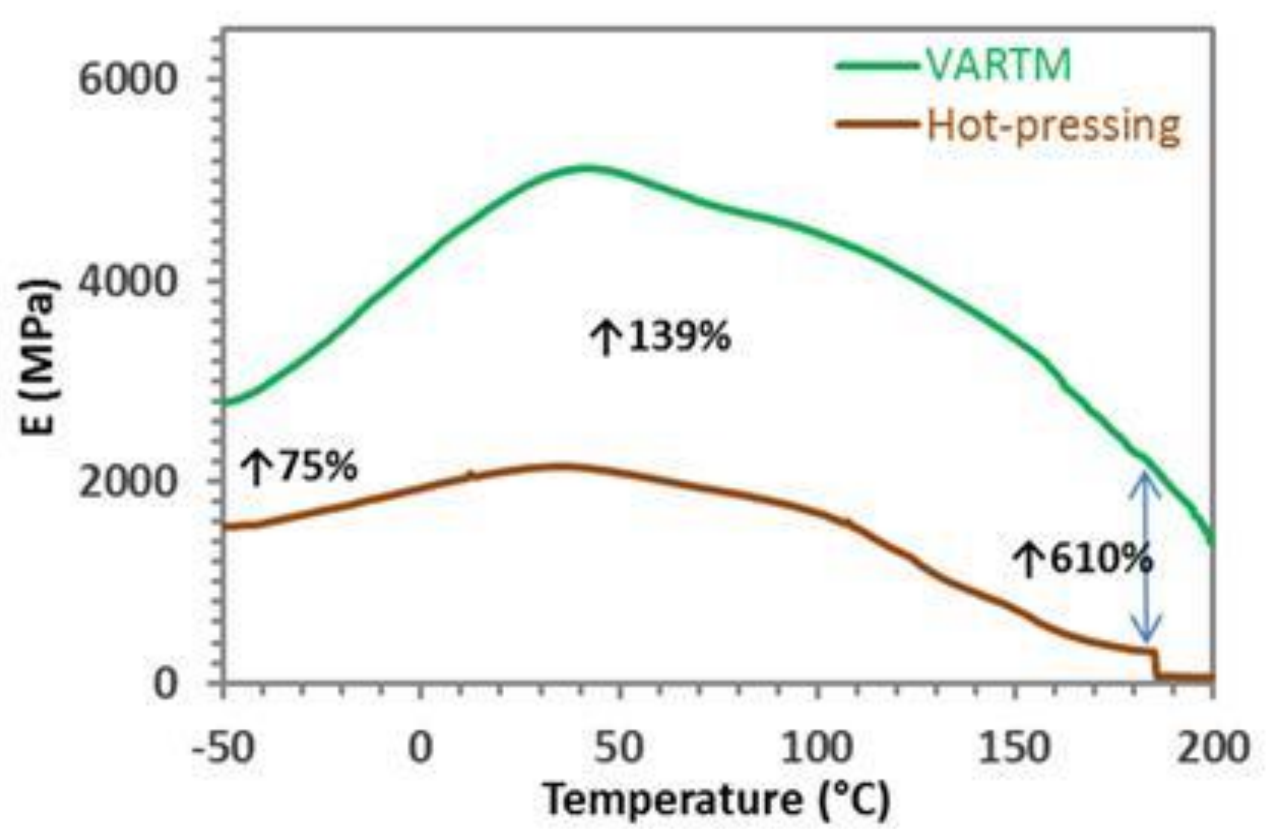
Property Comparison between VARIM and Compression Molding

	Sample size	MOE[1] (MPa)		MOR[2] (MPa)		Tensile strength (MPa)	
		Mean	Sd.[3]	Mean	Sd.[3]	Mean	Sd.[3]
Traditional hot-pressing	12	4185.6	1058.5	52.3	8.0	31.4	4.4
VARTM technology	12	6927.5	646.7	68.3	6.5	44.5	3.8
Increase (%)		65.5	-38.9	30.7	-19.2	41.7	-11.9

1.MOE-Bending Modulus of Elasticity
2.MOR-Bending Modulus of Rupture
3.Sd-Standard deviation

Dynamic Mechanical Analysis Performance

To characterize the material behavior at different temperatures



- The elastic moduli of the VARTM specimens at temperatures ranging from -50 to 200°C were increased by 2.3 to 11.1 times compared to the conventional compression molded composites.

SEM of the Fracture Surface of Tensile Sample: 1 mm scale

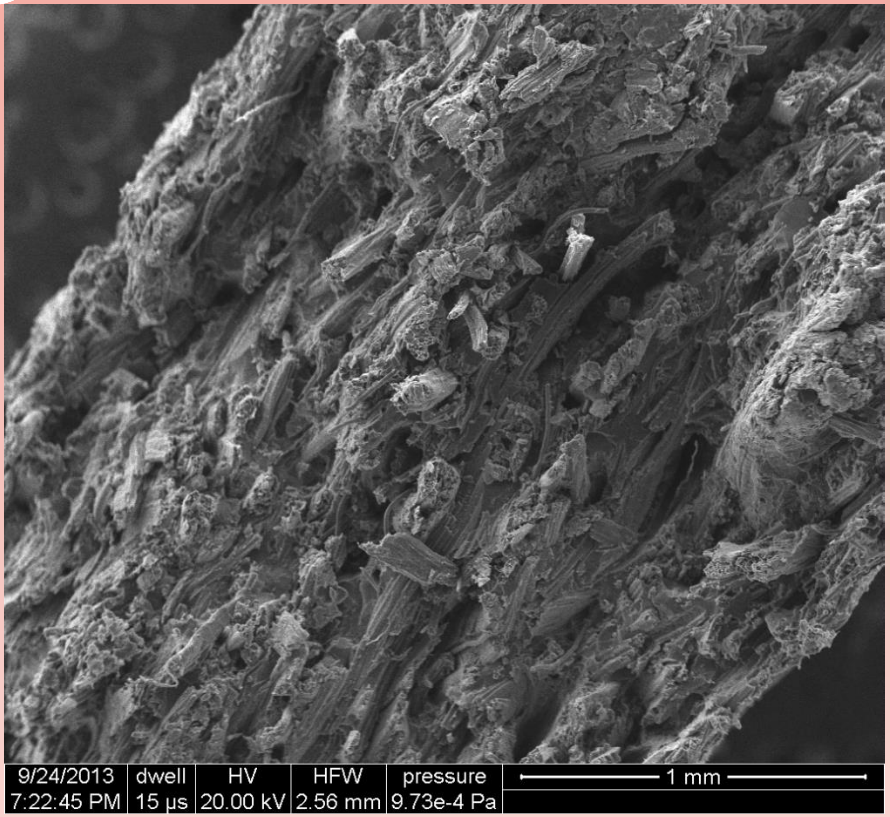


Fig.1 Traditional hot-pressing (1 mm)

Fig.2 VARIM technology (1 mm)

SEM of the Tensile Sample: 500 μm scale

Fig.3 Traditional hot-pressing (500 μm)

Fig.4 VARIM technology (500 μm)

SEM of the Tensile Sample: 50 μm scale

Fig.5 Traditional hot-pressing (50 μm)

Fig.6 VARIM technology (50 μm)

Porosity Measurement

Mercury intrusion porosimetry results

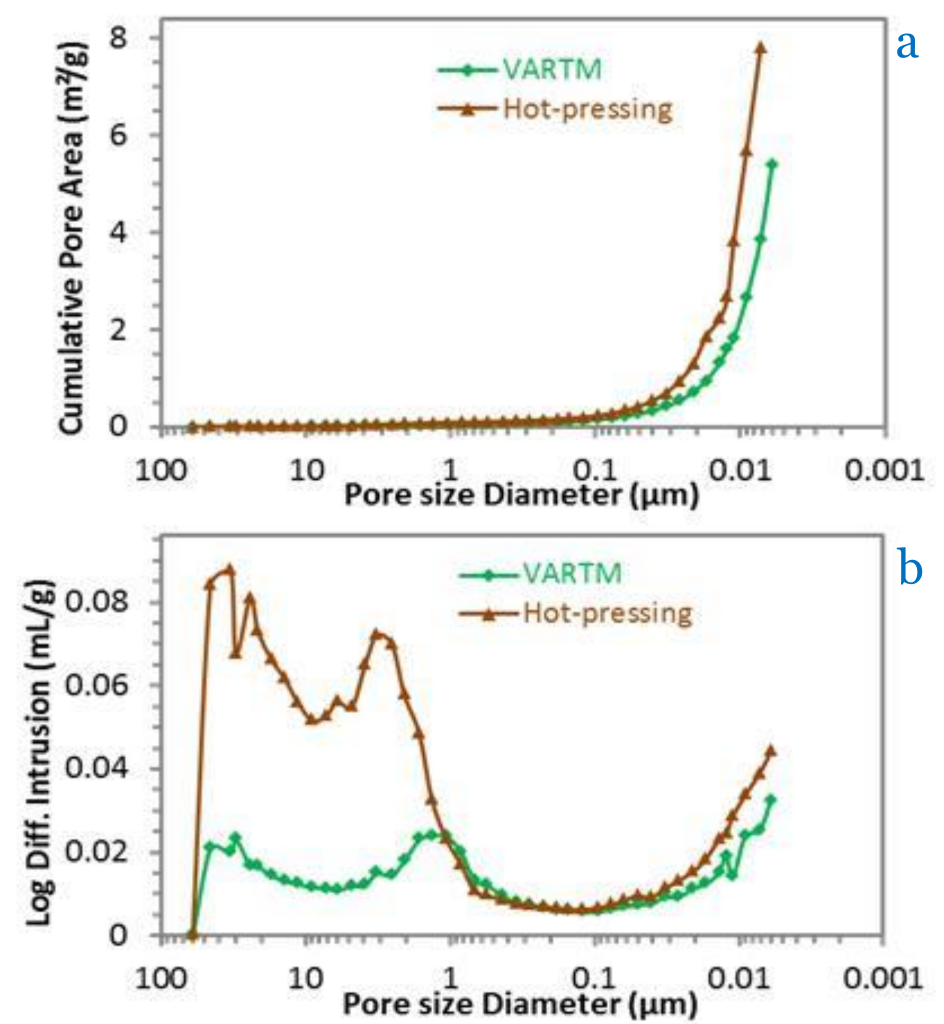
Table 2 Mercury intrusion porosimetry results of kenaf reinforced composites.

	Total pore area (m^2/g)	Median pore diameter (µm)	Average pore diameter (µm)	Porosity (%)
Hot-pressing	7.795	5.535	0.072	15.220
VATRM	5.393	1.209	0.041	3.628
Decrease (%)	30.8	78.2	43.0	76.2

- Micromeritics' AutoPore IV 9500

Measurements of Mercury Intrusion Porosity

1. **The cumulative pore area of VARTM specimens was up to 100% less than that for the compression molded sample for the pore sizes less than 0.1 µm.**
2. **The mercury intrusion amounts for the VARTM samples were up to three times less than that for the compression molded samples.**



Conclusions

- VARTM technology was successfully applied to keanf fibers and unsaturated polyester composites.
- Compared to traditional compression molded composites, the VARTM composites showed a 65.5% improvement in MOE, 30.7% in MOR and 41.7% in tensile strength.
- From DMA tests, the elastic moduli of the VARTM specimens at temperatures ranging from -50 to 200°C were increased by 2.3 to 11.1 times compared to the compression molded composites.
- With SEM observation, much less single-fiber pullout was observed for the VARTM composites compared to the compression molded specimens.
- From the mercury intrusion porosity measurement, the cumulative pore area of VARTM specimens was up to 100% less than that for the compression molded sample for the pore sizes less than 0.1 µm.
- The mercury intrusion amounts for the VARTM samples were up to three times less than that for the compression molded samples.

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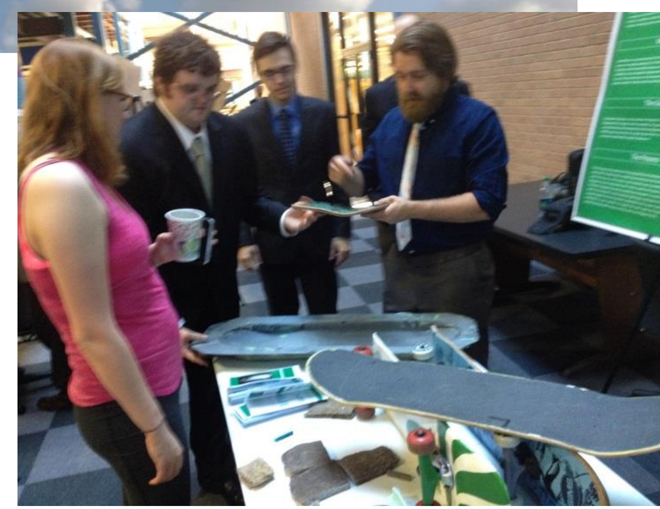
VARTM Skateboard



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ACKNOWLEDGEMENT

- University of North Texas Research Initiative
- NSF CMMI 1247008

Vacuum Assisted Resin Infusion Molding (VARIM) For Kenaf Fiber Composites

Thank you!

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