Composites Processing

ver. 1
Definition

• A microscopic mixture of two or more different materials. One typically being the continuous phase (matrix), and the other being the discontinuous phase (reinforcement).

• Its properties are strongly dependent on the composite structure.

• Ductility of matrix combined with stiffness of reinforcement.
Ceramic fiber composite

Polymer matrix composite
Types / Examples

• People
• Trees
• Fiber reinforced matrices
  – fiberglass - epoxy
• Particulate reinforced matrices
  – tires (carbon black in rubber, but it also has continuous fibers (steel or polymer belts))
Fibers/Particles Reinforcement

- Glass
- Kevlar
- Carbon
- Thermoplastics
- Alumina
- Boron
- SiC
- Steel
- $\text{Si}_3\text{N}_4$

- Silica
- Glass beads
- Talc
- Rocks
- Carbon black
- Calcium carbonate
Reinforcements

- Rovings
  - continuous
  - bulk
- Continuous strand mat
- Chopped strand mat
- Surface veils
Matrices

- Protects & separates reinforcement, transmits forces
- Polymer
  - PEEK, epoxy, polyester, polyurethane, rubber
- Metal
  - Al, Cu, Ni, Ti
- Ceramic
  - glass, cement
Honeycomb composites
C-17 Aircraft

- Carbon/epoxy
- Aramid/DuPont Nomex
- Carbon/aramid/epoxy
- Aramid/foam core
- Glass-fiber reinforced plastic
- Carbon/DuPont Nomex
Visby Corvette
Razzle Dazzle Camouflage
Stealth Ships
IsoTruss Bike

1.8 pounds (56)
Size: 50, 54, 56, 58, 60
IsoTruss® Technology
Carbon fiber/Kevlar
Lifetime warranty
Limited production
Processes

- Hand lay-up
- Vacuum bagging/autoclave
- Compression molding
  - SMC/BMC
- Liquid resin molding
- Resin transfer molding
Processes

- Pultrusion
- Filament winding
- Injection molding
- Thermoplastics processing
- Automated tape laying
Manual lay-up

- Definition: A process wherein the application of resin and reinforcement is done by hand onto a suitable mold surface. The resulting laminate is allowed to cure in place without further treatment.
Hand spray-up
Hand lay-up shop
Molds
Mold
Vacuum bag assembly
Vacuum bag

Vacuum Bag Lay-up

Breather

Bleeder

Composite laminate

Release coat/film

Porous release

Peel Ply

Barrier/release

Bleeder material

Vacuum bag film

Vacuum valve

Sealant tape

Tool

Photo: Georgia Tech
Lay-up

Material on stiffening structure

Vacuum bag and fittings attached
Autoclave
Autoclave

- Thermocouple
- Flexible vacuum line
- Manual valve
- Gage
- Vacuum header
- Vacuum receiver
- Vacuum pump
- Quick disconnect
- Vent
- Part with vacuum bag
- Autoclave cart
Delta II Rocket

- Vehicle Configuration: 7920-10C
- Launch Site: SLC-2 at VAFB
- Launch Date: 18 May 2000
- Unique Mission Requirements:
  - Dual Payload Attach Fitting (DPAF)
  - Two 37-pin PAF Umbilicals
  - One 24 inch Dia PLF Door
  - VC Level 3
  - Extended Mission Modifications
  - BBQ Thermal Roll (1 deg/sec)
Delta II rocket
Can be used with bulk molding compound (BMC)
Press shown is a 36" x 36" 4 mounting, electric hot press with an inline cool press.

(Photograph Courtesy of Automated Systems, Inc.)
Schematic of a compression molding press

FIG. 5.11 Schematic of a compression molding process.
Car parts with Sheet Molding Compound (SMC) - Prowler
SMC manufacture using a configuration that can make chopped-fiber SMC-R; continuous fiber SMC-C; or continuous, random SMC-C/R material.
Molding process
Fiber orientation

Compression Molding
Resin transfer molding (RTM) process

SCHEMATIC DIAGRAM

RESIN-INJECTION MACHINE

RESIN IN

CLAMPING PRESS

MOLD

PART

AIR OUT

WOVEN FIBER-PLACED IN MOLD PRIOR TO INJECTION

Preform Tool Injection Cure Demold

Georgia Institute of Technology
RTM applications

- Auto body panels
- Truck air deflectors
- Wind blades
- Chemical storage tanks
- Solar collectors (40 ft diameter, 36 parts)
- RV components
- Propellers
- Bathtub/shower units
- Antenna dishes
- Chairs
- Swim pool panels
Car parts
RTM automobile structure
Truck
Train Compartment
Plenum method for making preforms

CUTTER

AIR FLOW PORTS

BINDER SPRAY GUN

PERFORATED PREFORM SCREEN

TURNTABLE

EXHAUST FAN

ROVING
Schematic of high-speed RTM process
SCRIMP SYSTEM SCHEMATICS

- Process developed and patented by Seamann’s Composites
- Single-sided tooling
- Injection achieved through high-permeability surface layer to cause through-the-thickness flow
SCRIMP – Boat Hulls
Pultrusion process

Figure 1. Typical Pultrusion Process [1].
Fiber let-off

Fiber guides

Preforming

Resin impregnation

Curing die

Cut-off saw

Puller
Reinforcements

• Rovings
  – continuous
  – bulk

• Continuous strand mat

• Chopped strand mat

• Surface veils
Continuous fiber reinforcement in roving, mat and/or fabric forms are drawn through a resin bath to coat each fiber with a specially formulated resin mixture. The coated fibers are assembled by forming guides and then drawn through a heated die.

Cure of thermosetting resin is initiated by heat in the die and catalyst in the resin mix. The rate of reaction is controlled by heating and cooling zones in the die.

The resulting high strength profile is cut to length, ready for use as it leaves the pultrusion machine.
Hollow structure pultrusion process
RIM (Reaction Injection Molding) pultrusion

Figure 3. RIM (Reaction-Injected Molded) Pultrusion [3].
Exploded view of pultruded composite

Figure 6. Exploded View of Pultruded Composite [1].
Bank of America Building Spire
Pultruded bridges
Pultruded I-beam

Strongwell’s pultruded double-webbed internally-flanged 36-inch composite beam incorporates carbon fiber in the top and bottom flanges.
Filament winding

- Hoop windings
- Mandrel
- Helical windings
- Machine drive
- Resin bath
- Filament feed
- Filament carriage
- Fiber spools
GT’s machine
Filament winding machines
Delta IV Rocket faring mandrel
Reusable Mandrels

Figure 1: A Veriflex™ cylinder is fabricated.

Figure 2: The cylinder is placed in a clamshell mold, heated, and blow-molded into a complex-shaped mandrel.
Reusable Mandrels

Figure 3: The mandrel is cooled below the transition temperature resulting in a rigid mandrel.

Figure 4: The mandrel is filament-wound and then cured. The cure process for the composite does not affect the mandrel.
Reusable Mandrels

Figure 5: After the composite is cured, the Veriflex™ mandrel is heated above its activation temperature. The Veriflex™ then becomes pliable and is removed. The transition temperature does not affect the composite.

Figure 6: The complex part is completed. The cylindrical Veriflex™ mandrel, which returned to its "memory" shape while above its transition temperature, can be reused.
Creel tensioners
Integral head resin wet-out bath
Winding pins for low angle winding
Continuous curing oven
Layout of a computer-controlled filament-winding machine
Gas tanks
Aerospace parts

F-16

Patriot missile

Soviet missile
Rocket Motor Casings
Tape laying – 787 fuselage
Tape laying – 787 fuselage
Composite motors
Sporting goods
Glass epoxy filament-wound 9-foot-diameter by 55-foot-long assembled railway tank car

Figure 5. Glass epoxy filament-wound 9-foot-diameter by 55-foot-long assembled railway tank car.
Pipe machine and cure oven
Light pole
Thermoplastics processing
Injection molding

Clamp  Mold  Barrel  Hopper
Injection molding

- Hopper
- Barrel
- Pellets
- Nozzle
- Screw
- Heaters
- Cavity
- Mold
- Clamp
- Motor/Drive
Roll forming
Roll-formed part

Figure 1
PHOTOGRAPH OF FORMED AND UNFORMED “T” SHAPES
Matched die forming

- Sample and holder
- Weights
- Alignment pins
- Adjustment bolts
Press forming of LDF
(long discontinuous fibers)

Heat material

Transfer into heated dies

Clamp and thermoform

Formed component after trimming
Compression molding
Compression molding sequence
Hydroforming

Fig. 11 Hydroforming
Diaphragm forming
Diaphragm forming

A

PRESSURE/VACUUM VALVE

PRESSURE/CHAMBER

RADIANT HEATERS

VACUUM MANIFOLD

SUPERPLASTIC ALUMINUM DIAPHRAGMS

COMPOSITE LAYUP

TOOL

MOBILE TOOL PLATFORM

B

PRESSURE, P

PRESSURE, P+

C

PRESSURE, P

D

PRESSURE, P+

PRESSURE, P
Vacuum forming in autoclave

Fig. 17 Vacuum-forming fixture design for use in autoclaves
Stretch forming
Tape laying

Fig. 12 Automated tape-laying process
Fig. 13  Thermoplastic filament winding with continuous consolidation
Automated Tow Placement - Thermoplastics
Robotic thermoplastic ATP machine

NASA Langley
Filament winding thermoplastic ATP machines
Filament winding thermoset ATP machine
Large ATP machine
Typical parts