Composites & Manufacturing

Last Briefing Session

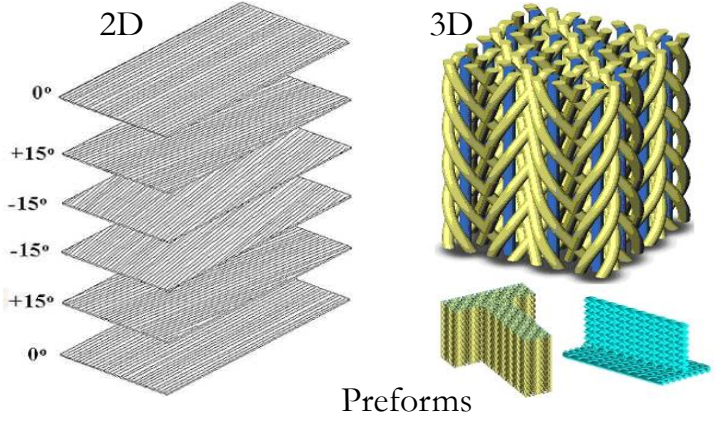
Composites

A *judicious* combination of two or more materials that produces a *synergistic* effect.

A material system composed of two or more physically distinct phases whose combination produces aggregate properties that are different from any of those of its constituents independently.

What are Composite Materials?

- A combination involving physical bonding, chemical bonding or both, of two or materials in which constituent materials can be individually identified by visual means.
- Generally, reinforcements provide strength and stiffness and matrix prevents reinforcement from environment and maintains arrangement of reinforcement.
- Mechanical properties per unit weight of composite materials are better than conventional materials.
- Most common type of composite material is fiber- reinforced polymer composite or fiber-reinforced plastic (FRP).



Different forms of reinforcing materials in fiber-reinforced composites

Fiber-reinforced composites

Common materials:

- Fibers: Glass fiber, carbon fiber, Kevlar, etc.
- Matrix: Epoxy, polyesters, etc.

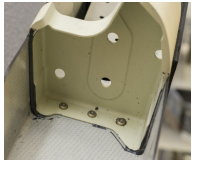
GFRP panel for automobile

Plyboard

Manufacturing techni

- Hand layup
- Autoclave molding
- Compression molding
- Reaction injection molding
- Resin transfer molding
- Pultrusion
- Filament winding

Ballistic helmet



Aircraft component

CFRP panel for aerospace application

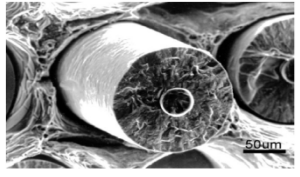
Composites

A composite material consists of two phases:

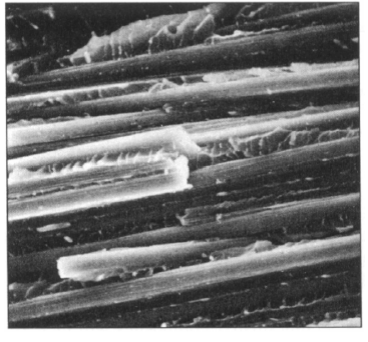
- Primary
  - Forms the matrix within which the secondary phase is embedded
  - Any of three basic material types: polymers, metals, or ceramics
- Secondary
  - Referred to as the embedded phase or called the reinforcing agent
  - Serves to strengthen the composite. (fibers, particles, etc.)
  - Can be one of the three basic materials or an element such as carbon or boron

Classification of composite material

- **Metal Matrix Composites (MMCs)**
  - Include mixtures of ceramics and metals, such as cemented carbides and other cermets, as well as aluminum or magnesium reinforced by strong, high stiffness fibers
- **Ceramic Matrix Composites (CMCs)**
  - Least common composite matrix. Aluminum oxide and silicon carbide are materials that can be embedded with fibers for improved properties, especially in high temperature applications
- **Polymer Matrix Composites (PMCs)**
  - Thermosetting resins are the most widely used polymers in PMCs. Epoxy and polyester are commonly mixed with fiber reinforcement.



Ceramic fiber composite


Polymer matrix composite

Reinforcements

- Rovings
  - continuous
  - bulk

- Continuous strand mat
- Chopped strand mat

- Surface veils

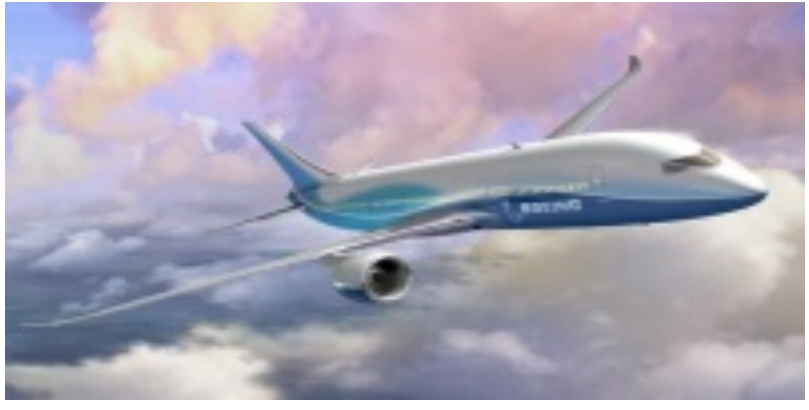
POLYMER MATRIX COMPOSITES

Attractive features of FRP:

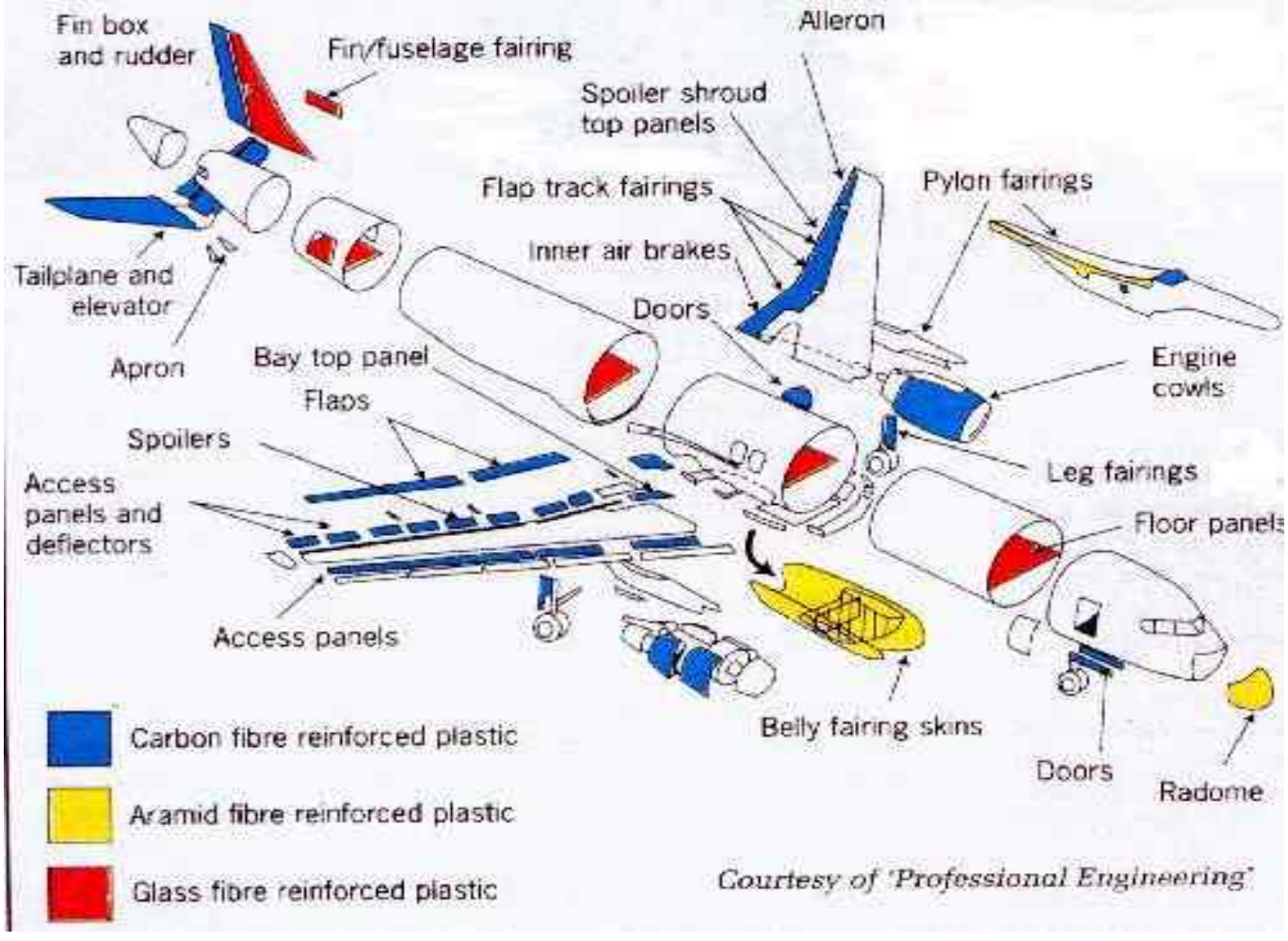
- high strength-to-weight ratio
- high modulus-to-weight ratio
- low specific gravity
- good fatigue strength
- good corrosion resistance, although polymers are soluble in various chemicals
- low thermal expansion, leading to good dimensional stability
- significant anisotropy in properties

AEROSPACE

- **Boeing's 7E7 to be 50% Composite**
- Composites will account for 50 percent of the weight of the proposed 200 to 300 seat jet, about four times the amount on Boeing's last new jet, the 777 -- while aluminium would fall to 15 or 20 percent from 70 percent.



Composites


Fin box and rudder
Fin/fuselage fairing
Alleron
Spoiler shroud top panels
Flap track fairings
Pylon fairings
Inner air brakes
Tailplane and elevator
Doors
Apron
Bay top panel
Engine cowls
Flaps
Spoilers
Leg fairings
Access panels and deflectors
Floor panels
Access panels
Belly fairing skins
Doors
Radome
Carbon fibre reinforced plastic
Aramid fibre reinforced plastic
Glass fibre reinforced plastic
Courtesy of 'Professional Engineering'

Composites

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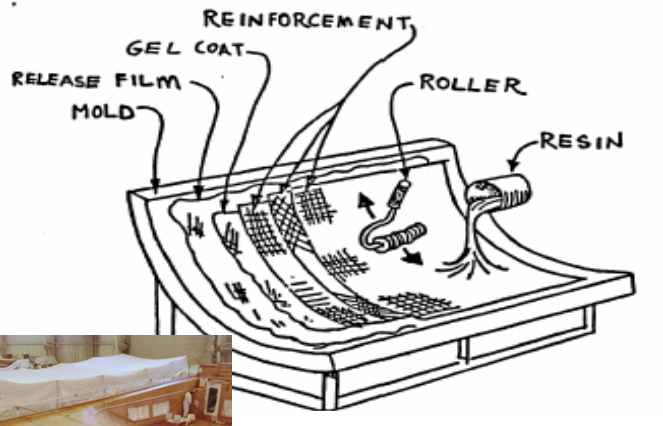
Hand Layup

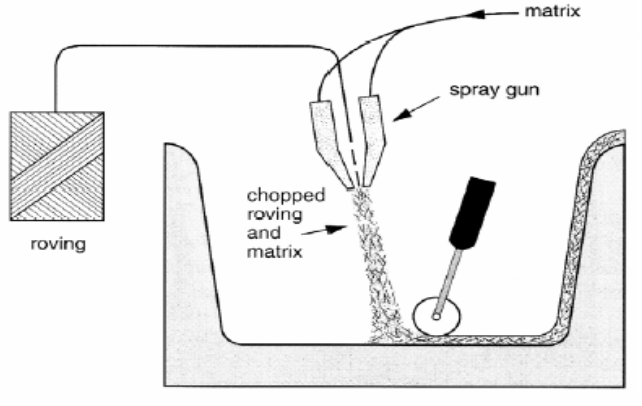
- In this process resin and reinforcements are applied by hand onto a suitable mold surface.
- Resulting laminate is allowed to cure without further treatment.
- Products include boats, chairs, sink, etc.



Hand Layup

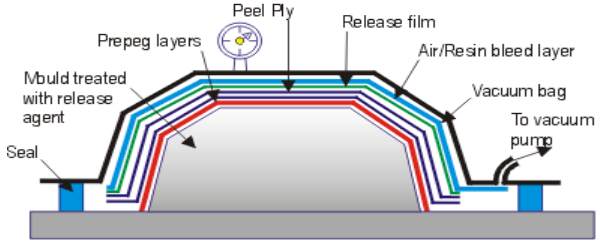
Large containers

Chair

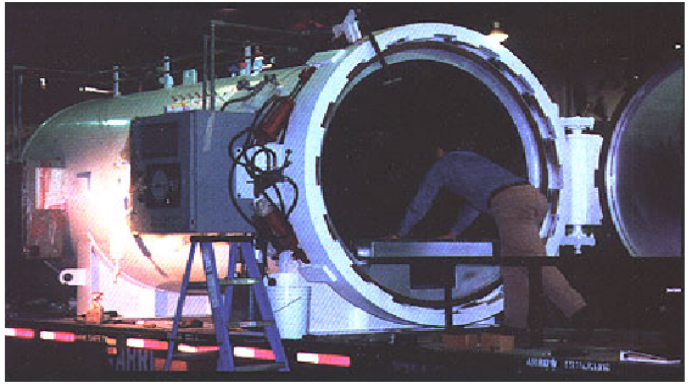


Spray layup

Autoclave Molding



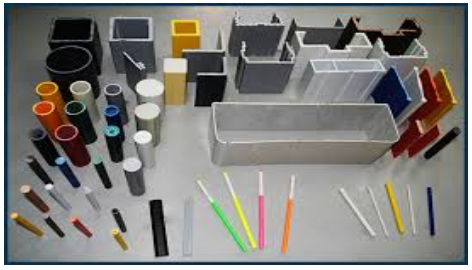
- Predominantly used in the aerospace industry.
- The starting material for this process is a prepreg that contains fibers in a partially cured epoxy resin. Typically, a prepreg contains 42 weight percent of resin.
- The excess resin flowing out from the prepreg removes the entrapped air and residual solvents, which in turn reduces the void content in the laminate.
- As the prepreg is heated in the autoclave, the resin viscosity in the prepreg plies first decreases, then attains a minimum, and then increases rapidly as the curing reaction.



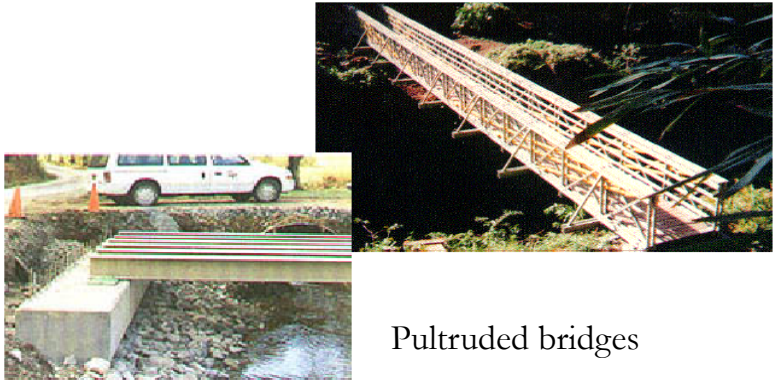
An autoclave

Pultrusion

- A continuous molding process for producing long straight structural members of constant-cross sectional area.
- The major constituent in a pultruded product is longitudinally oriented continuous strand rovings.
- Several layers of mats of woven rovings are added near the outer surface to improve its transverse strength. The total fiber content in a pultruded member up to 70% by weight.
- Products: Solids rods, hollow tubes, flat sheets and various types of beams.

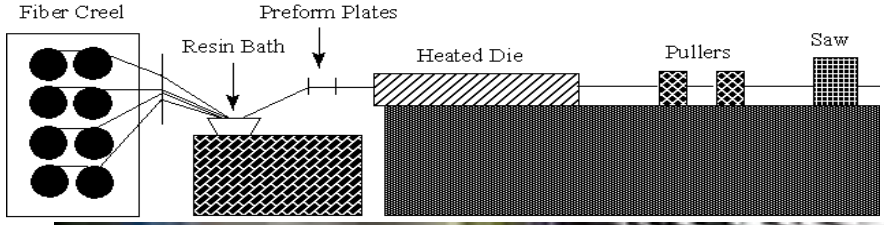


Structural beam sections



Pultruded bridges

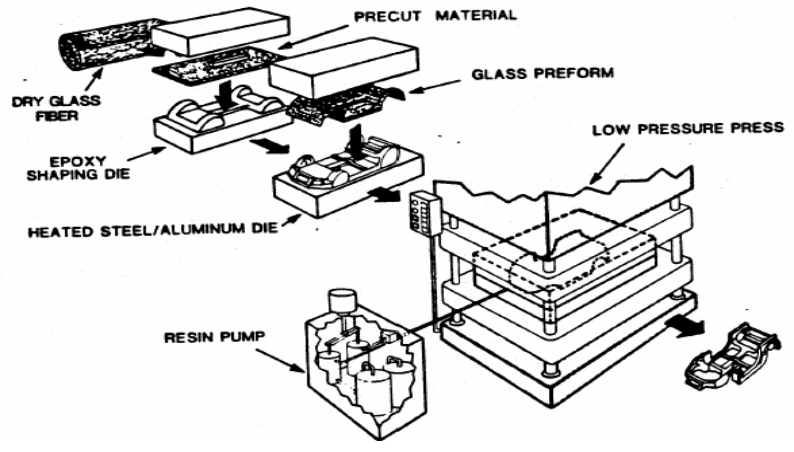
Pultrusion



Schematic of pultrusion

Resin Transfer Molding (RTM)

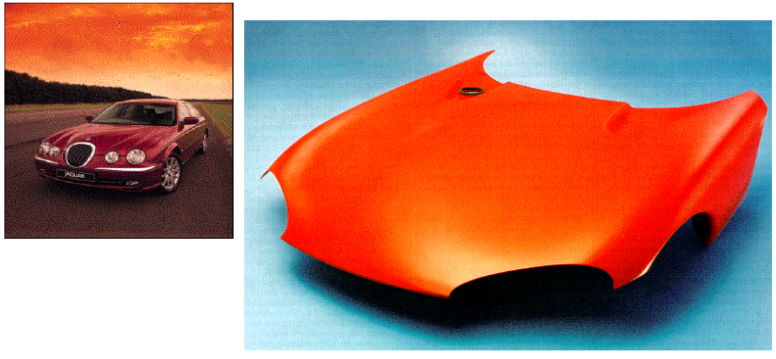
- Continuous strand mat placed in the bottom half of a two-part mold ,mold is closed, catalyzed liquid resin is injected into the mold via a centrally located sprue.
- The resin injection point is usually at the lowest point of the mold cavity.
- The injection pressure is in the range of 69-690kpa.
- Resin displaces the entrapped air through air vents and impregnates the fibers.



Schematic of resin transfer molding

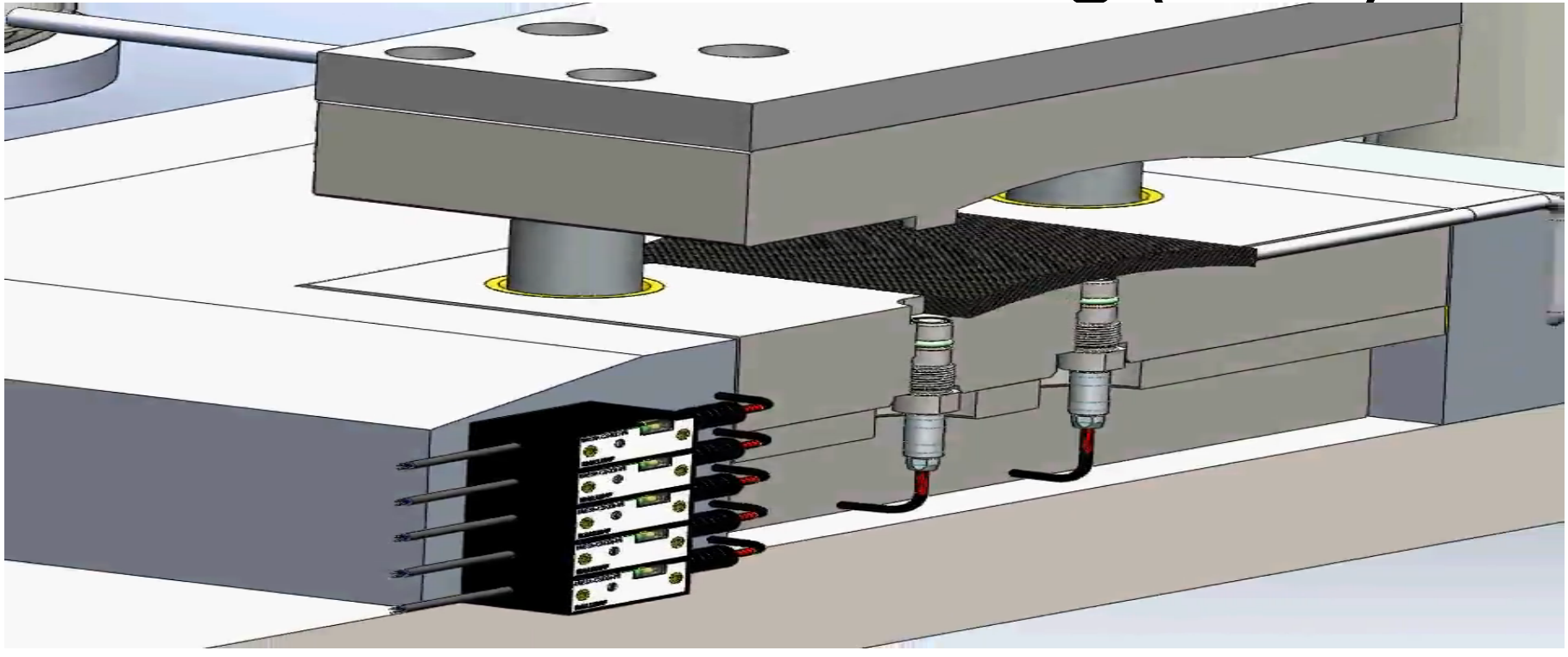
Resin Transfer Molding (RTM)

- Depending on the resin-catalyst system used , curing is performed either at room temperature or at an elevated temperature in an air-circulating oven.
- After the cured part pulled out of the mold, it is often necessary to trim the part at the outer edges to conform to the exact dimensions.
- Applications: Battery rack, body panels, dashboard mounting, small fans, etc.



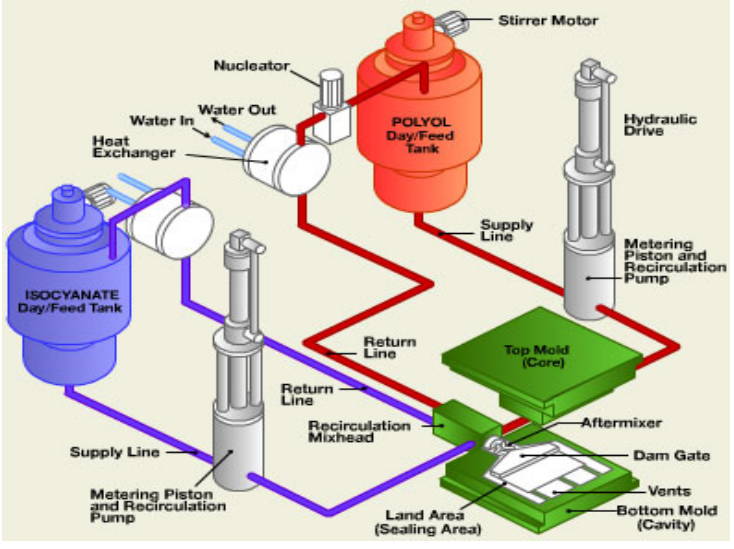
Automotive body panels

Resin Transfer Molding (RTM)



Reaction Injection Molding (RIM)

- Two highly reactive, low-viscosity liquid streams are impinged on each other at high speeds in a mixing chamber before injection.
- Process uses dry fiber preforms, placed in the mold, prior to resin injection.
- It involves low plant investment, low process energy, low clamping pressure requirement, low product density
- Applications: Car bumper, head rests, steering wheels, TV cabinet, window frame, refrigerator liners, etc.

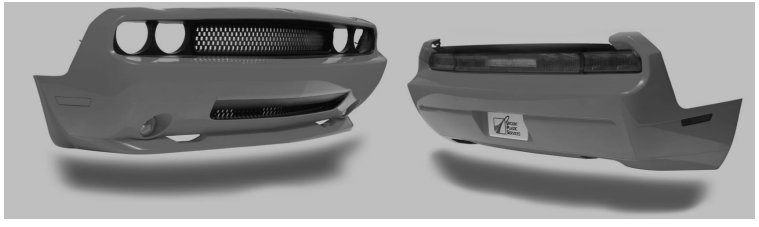


Schematic of reaction injection molding

Reaction Injection Molding

Structural Reaction Injection Molding (SRIM)

- Uses dry fiber preforms, placed in the mold, prior to resin injection.
- The difference in RTM and SRIM is mainly in resin reactivity, which is higher for SRIM resin than RTM resin.
- Resin flows through layers of dry reinforcement while the curing reaction continues.
- It is imperative that the resin fills the mold cavity completely and wets out the reinforcement before arriving at the gel point, thus the resin velocity must be low.



Car bumper

Compression Molding

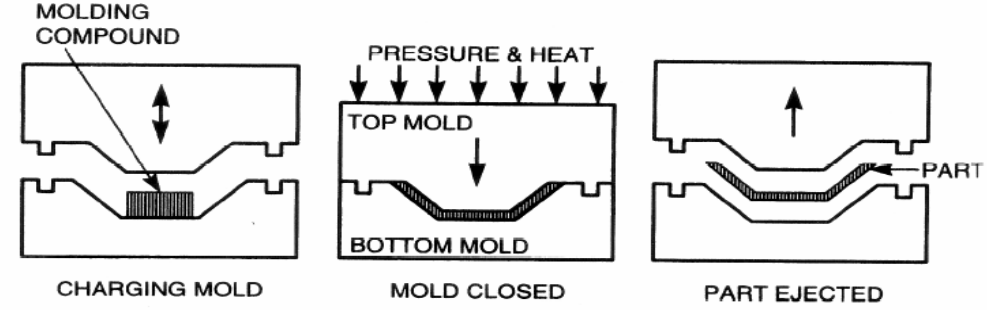
- This process is used produce parts of complex geometry in short periods of time.
- The compression molding process is suitable for the high volume production of composite parts.
- The compression molding operation begins with the placement of a precut and weighed amount of sheet molding compound (SMC), usually stack of several rectangular plies called the charge, on to the bottom half of a preheated mold cavity.
- The ply dimensions are selected to cover 60-70% of the mold surface area.
- The mold is closed quickly after the charge placement, and the top half of the mold is lowered at a constant rate until the pressure on the charge increases to a preset level. With increasing pressure the SMC material in the mold starts to flow & fill the cavity.

Compression molding

- Flow of the material is required to expel air entrapped in the mold as well as in the charge. Depending on the part complexity, length of flow, and-fiber content, the molding pressure may vary from 1.4 to 34.5 MPa.
- The mold temperature is usually in the range of 130-160 degree centigrade after a reasonable degree of cure is achieved under pressure the mold is opened, and the part is removed, often with the aid of ejector pins.
- During molding, a complex heat transfer and viscous flow phenomenon takes place in the cavity.
- Involves high tooling investments, material cost, requirement of operator skill and high capital investment.
- Applications: Structural automotive components, including rods, wheels, bumpers & leaf springs.

Car parts from SMC

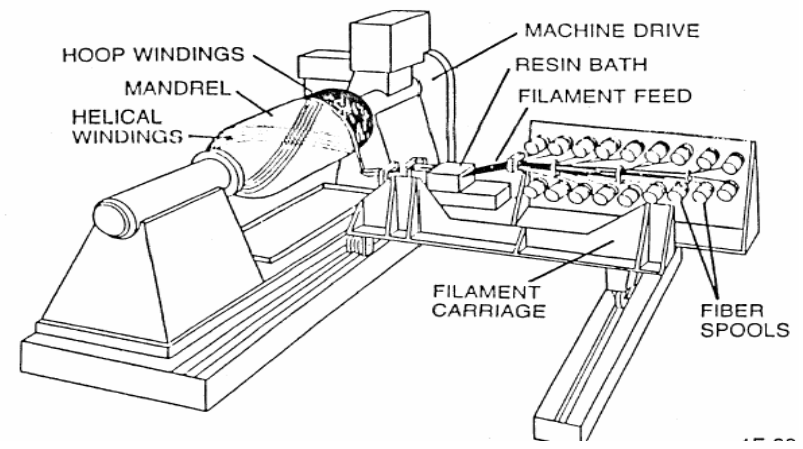
Compression Molding



Schematic of compression molding

Filament Winding

- A band of continuous resin-impregnated rovings or monofilaments is wrapped around a rotating mandrel and cured to produce axisymmetric hollow parts.
- A large number of fiber rovings are pulled from a series of creels into a liquid resin bath containing liquid resin, catalyst, and other ingredients, such as pigments and UV absorbers.
- Applications: Automotive drive shafts, helicopter blades, oxygen tanks, pipelines, spherical pressure vessels, conical rocket motor cases, and large underground gasoline storage tanks.



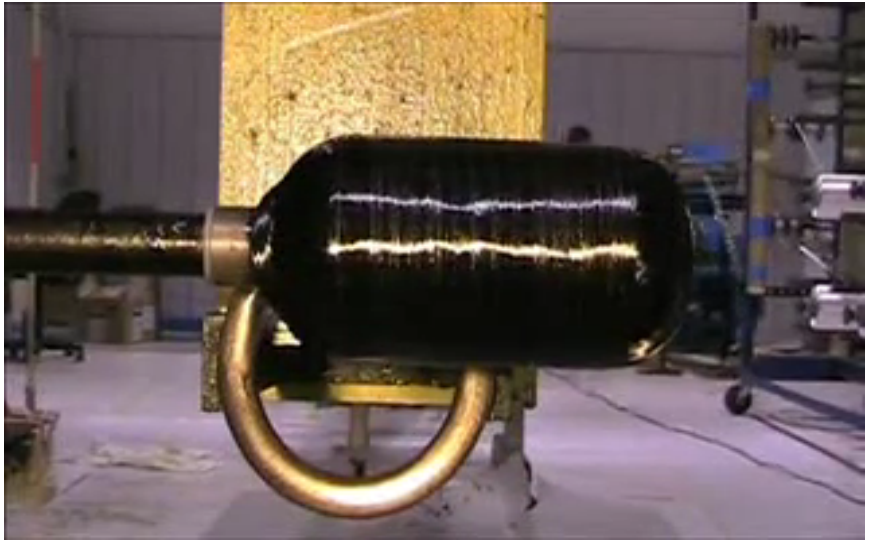
Schematic of filament winding

Filament Winding

- Just before entering the resin bath, the rovings are usually gathered into a band by passing them through a textile thread board or a stainless steel comb.
- At the end of the resin tank, the resin-impregnated rovings are pulled through a wiping device that removes the excess resin from the rovings and controls the resin coating thickness around each roving.
- The most commonly used wiping device is a set of squeeze roller in which the position of top roller is adjusted to control the resin content as well as the tension in fiber rovings.

Rocket fairings

Filament Winding



Gas tanks

IITD contribution for Societal Impact through Product Realization

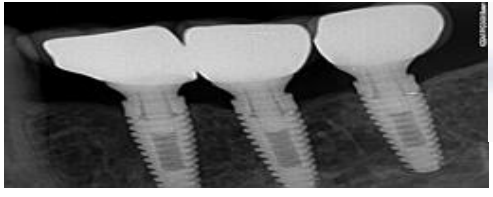
Prof Naresh Bhatnagar

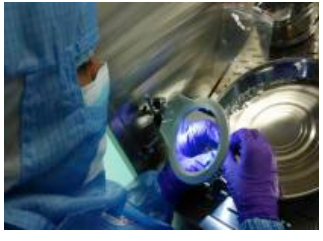
Mechanical Engineering Department

Technology and Products developed and transferred to Industry

Dental Implants

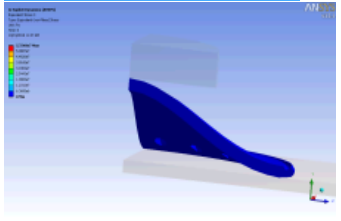
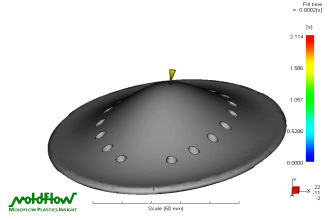


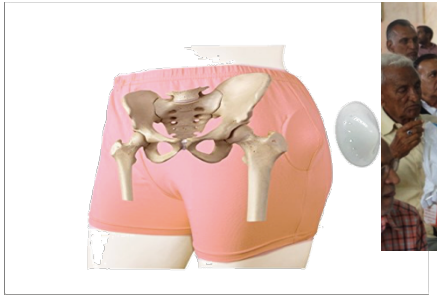


Hip protection Device for Elderly

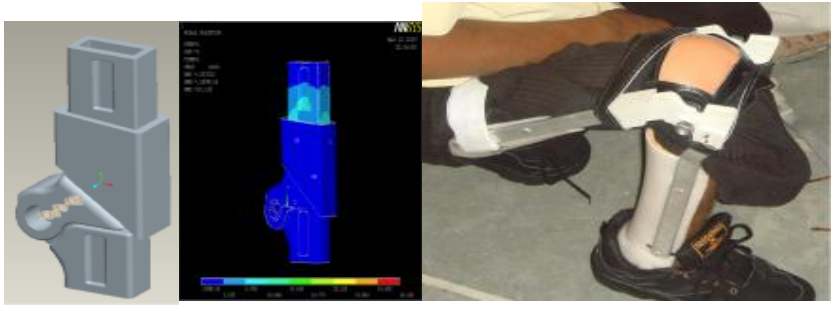


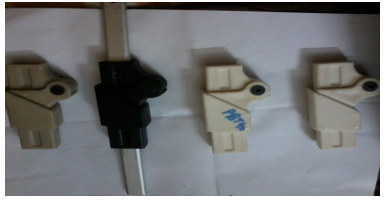





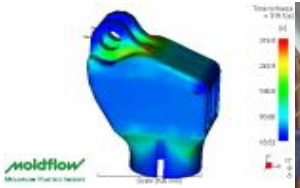

Products awaiting to reach masses

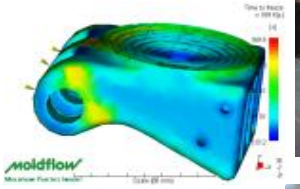
Light weight Orthotic Knee Joint for Polio and Cerebral Palsy patients





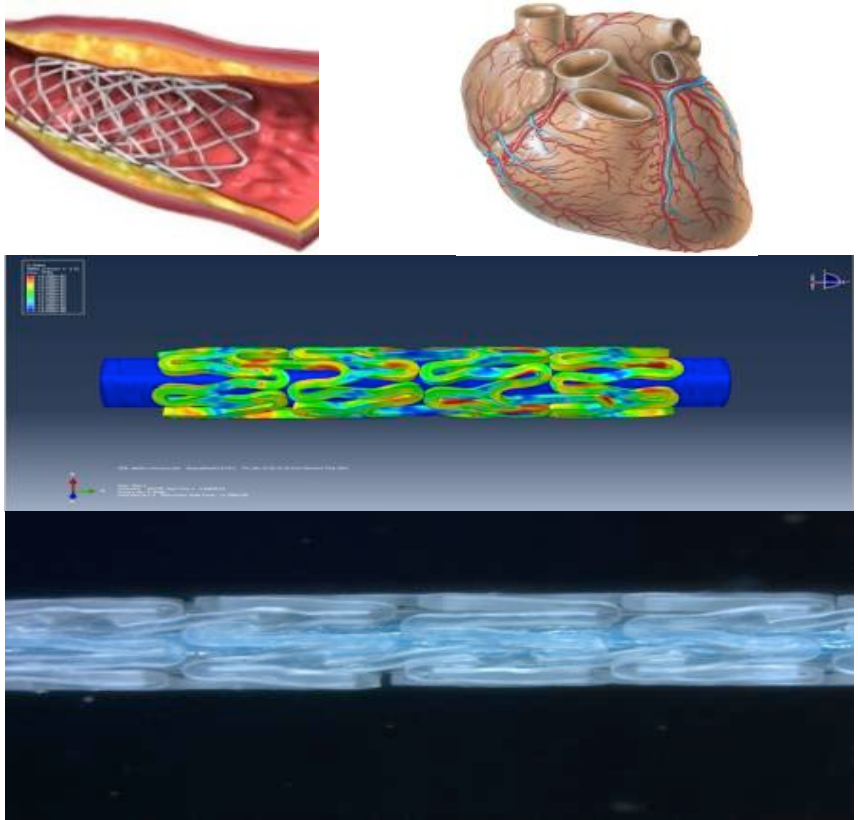
Light weight Polycentric Prosthetic Knee joint for Amputees above Knee



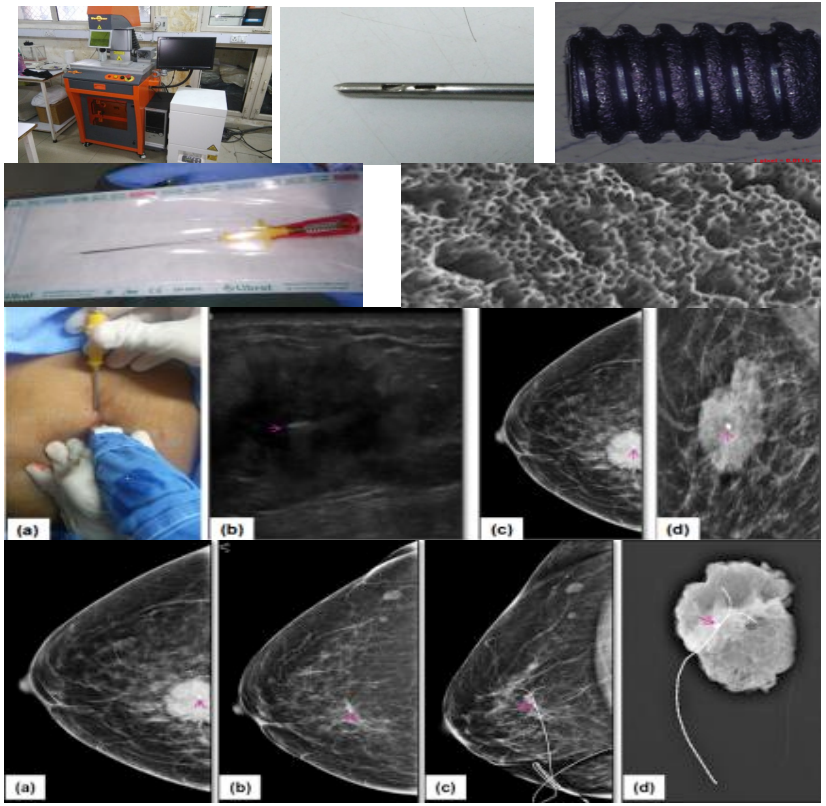


Product Realization in Progress

Bioresorbable Cardiac Stent



Breast Cancer Tumor Marker

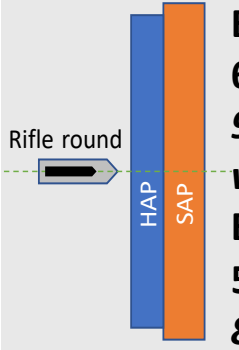


Advanced Ballistics and High Energy Defeat (ABHED-*The Protector*) Bullet Proof Jacket Developed at IIT Delhi (..The Lightest Possible Globally with Minimum Back-face Signature…)

- 360° Protection from rifle rounds
- Designed to defeat multiple bullets of AK-47 and Armor Piercing Sniper rifle, SLR, Machine gun & Carbines

Modular Construction

HAP defeats rifle rounds and SAP reduces back face trauma



BIS Threat Level 6

9.3 kg total weight

BIS Threat Level 5

8 kg total weight

Low Back face Trauma (<25 mm)

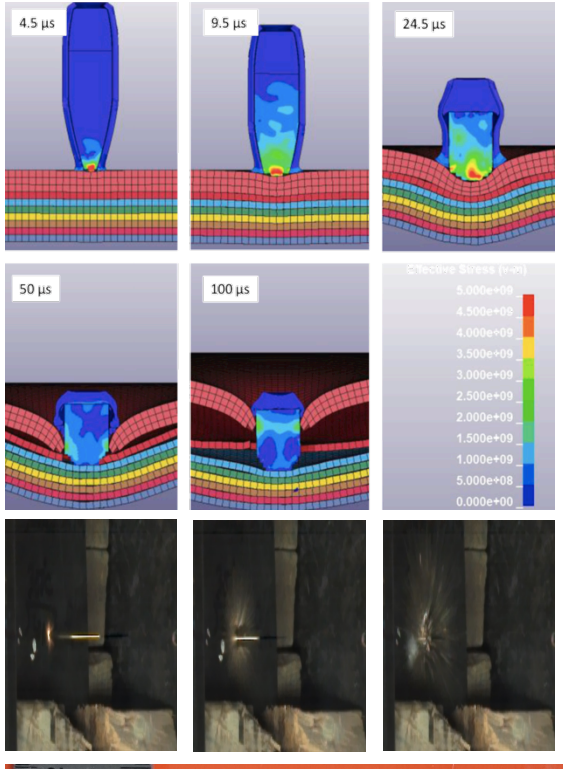
Less injury to wearer and quick recovery

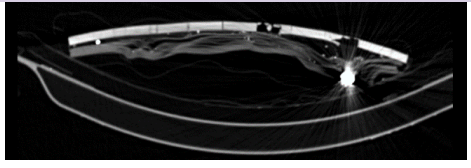
Defeats Highest Threats in Indian and International Standards for Personal Body Armor

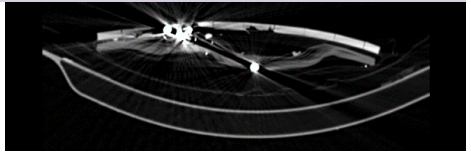
BIS 17051:2018, Indian Army GSQR 1438, NIJ 0101.06

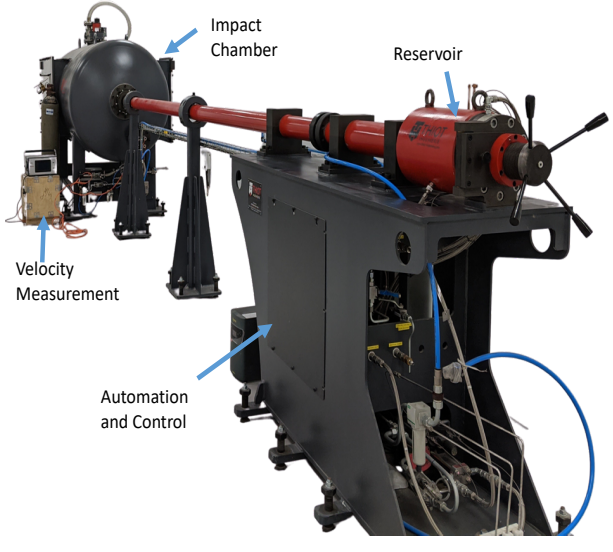
The Engineering of ABHED

- ABHED design is based on experimental and numerical analysis
- CT imaging of armor and residual cores after ballistic testing were used for understanding phenomenon

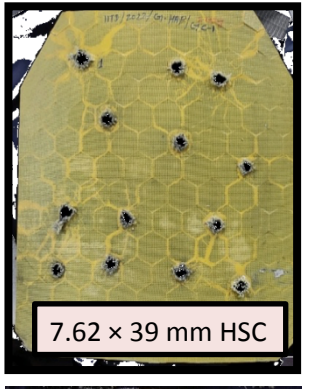


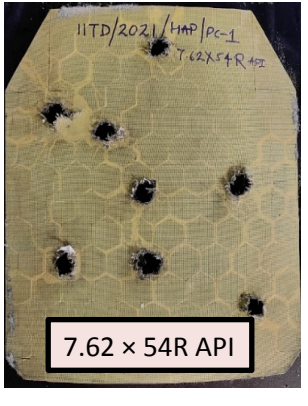






ABHED can defeat 8 shots of 7.62 × 54R API/ 7.62 × 39 mm HSC/ 7.62 × 51 mm Pb/ fired from Dragunov, AK-47 SLR, SMC





TOT available to Indian Industries at: *https://www.drdo.gov.in/transfer-technologies*

Thank you and Best of Luck