# Introduction to Aerospace Engineering

## Lecture slides


# Manufacturing aspects

## Metals & Composites

Faculty of Aerospace Engineering

6-12-2011


# Learning objectives

## Student should be able to…

- Metals
  - Describe the three main manufacturing processes in metals
  - List typical processes for each category
- Composites
  - List typical manufacturing processes in composites

# Metals

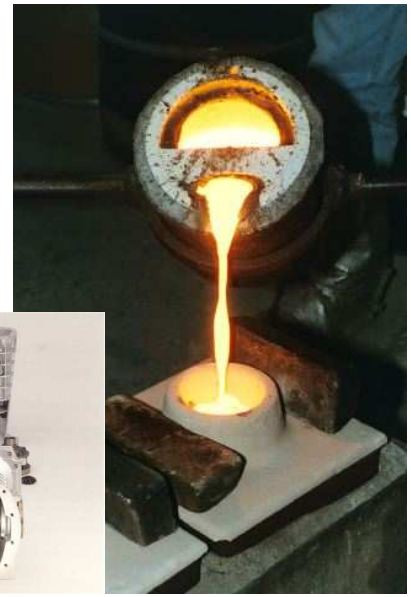
What are typical Properties of Metal alloys you can use to create a metal component or product?

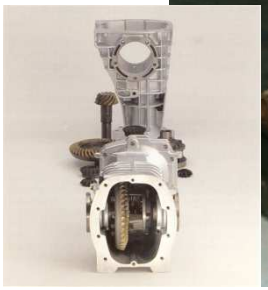
Melting – you can liquify a metal (alloy)
Plastic deformation at Room temp. – deforming by high forces

# Metals

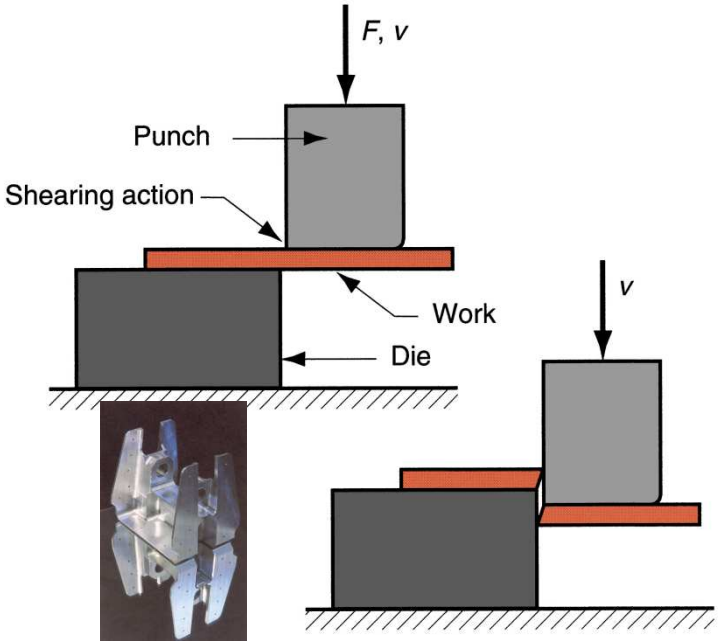
## Categories of manufacturing processes

- Liquid casting



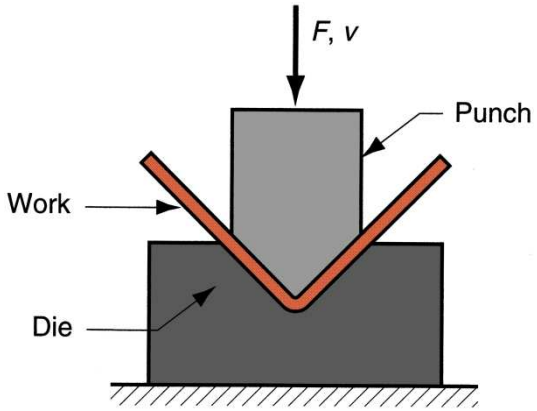


- Shearing



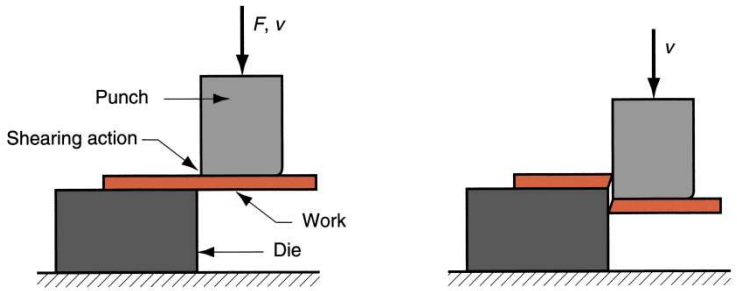



- Forming



# Metals

## Shearing processes



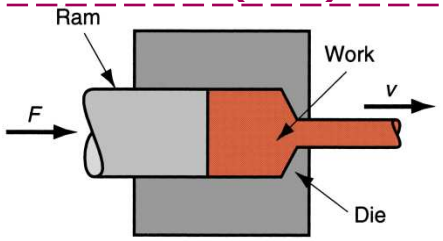

- Solid state cutting & milling processes
  - Large components with small geometrical tolerances possible
- Geometrical tolerances
  - Definition: Maximum variation allowed in form or positioning
- Type of tolerance
  - Form control
  - Flatness
  - Positioning
  - Perpendicular/parallel
  - Etc.

# Metals

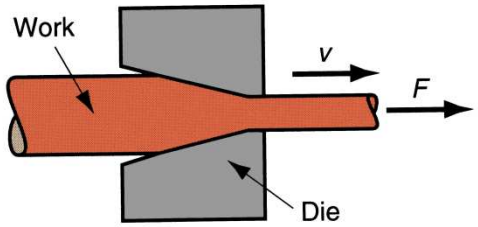
## Typical forming processes

### Bulk material (hot)

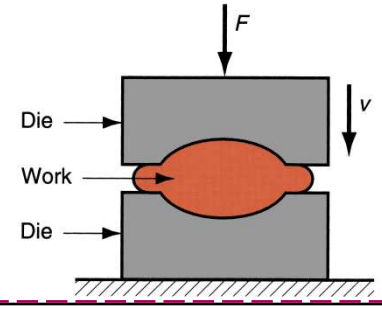
- Extrusion




- Drawing

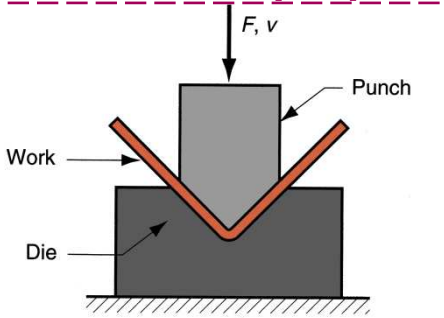



- Forging

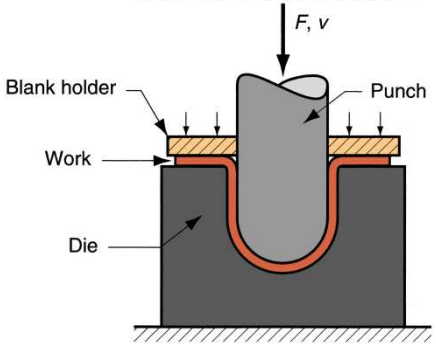



### Sheet/plate material (RT)

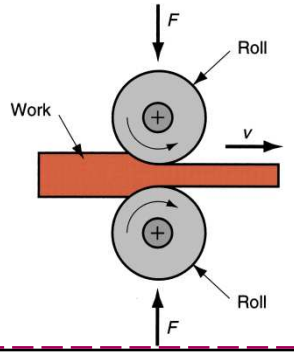
Bending




Drawing




Rolling

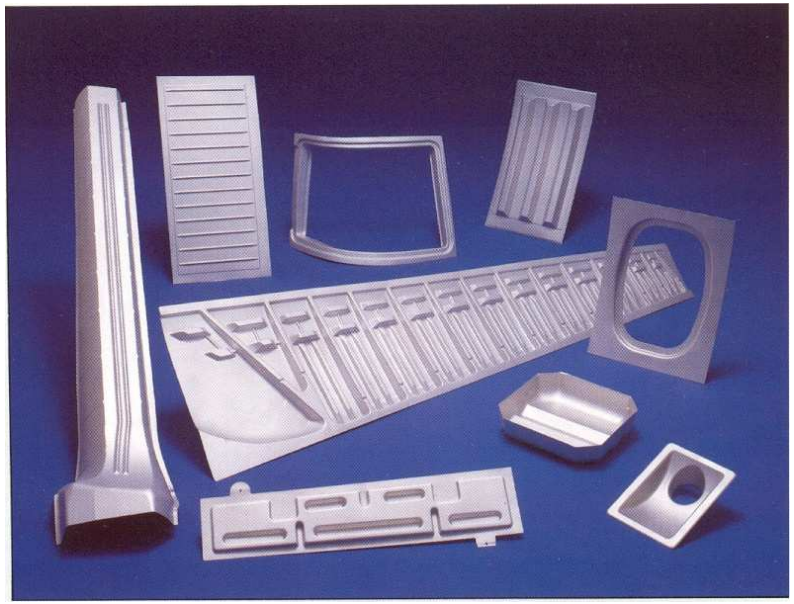


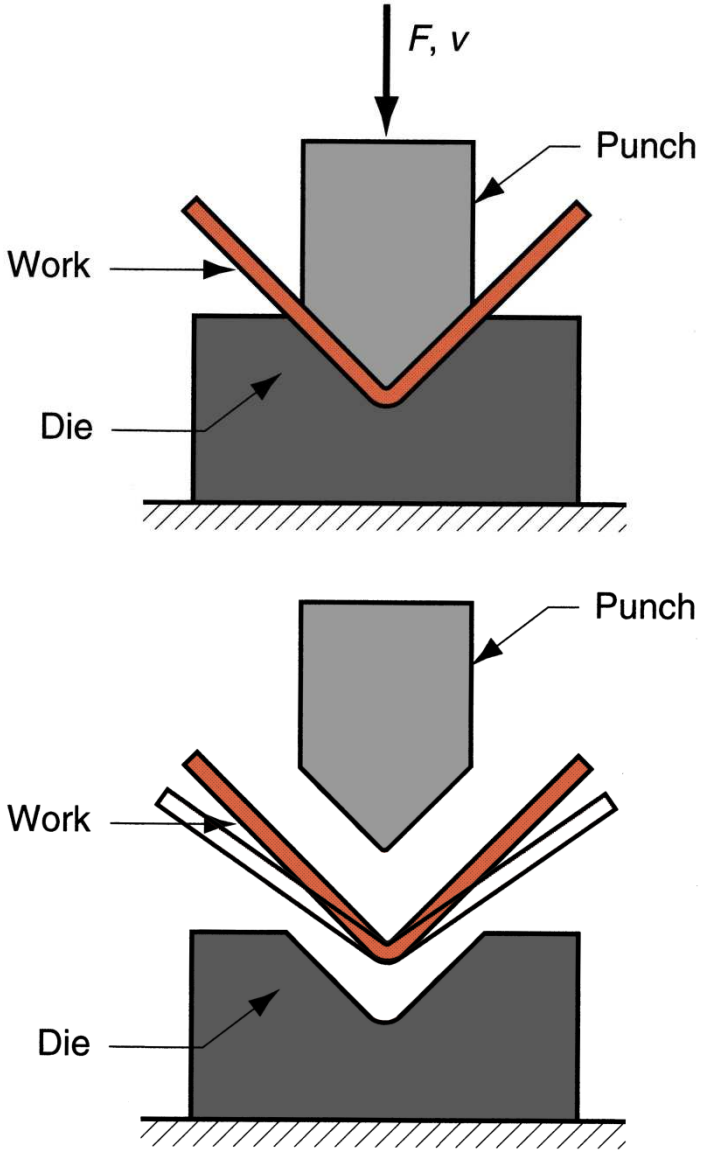
# Metals

## Forming process

- Consider sheet bending

- Elastic spring back…

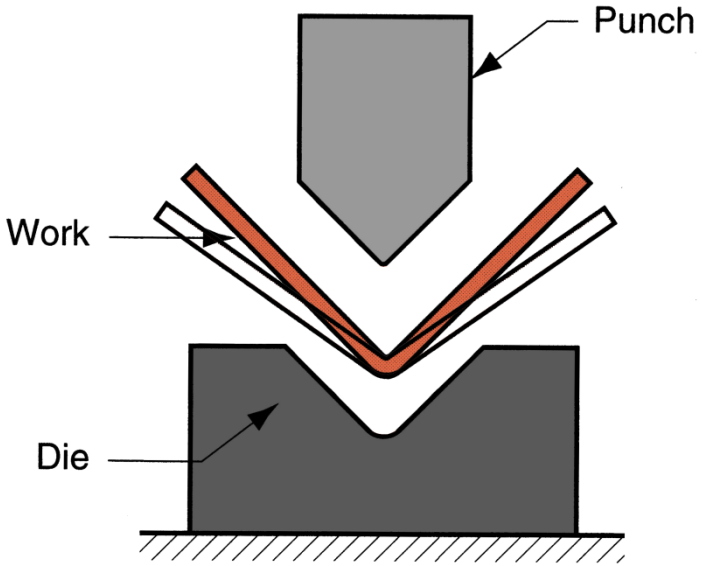


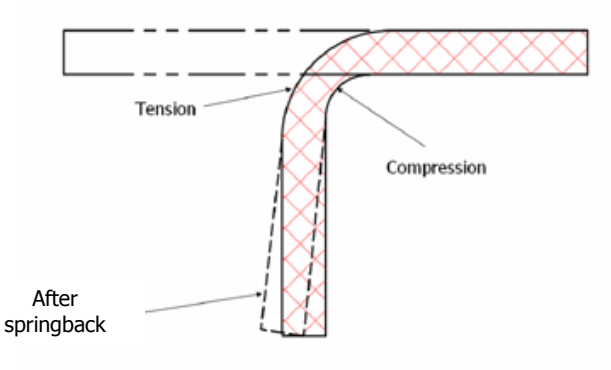


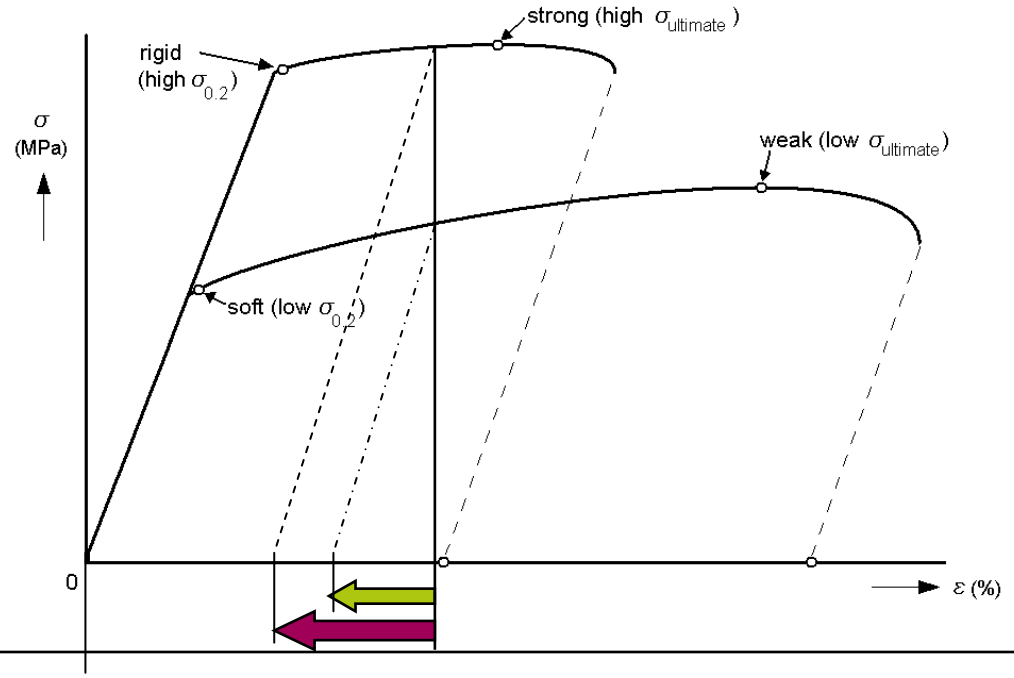
# Metals

## Forming process

- Sheet bending (elastic spring back)
  - Less spring back for low yield strength
  - Design requires high yield strength!!



# Metals

## Forming process

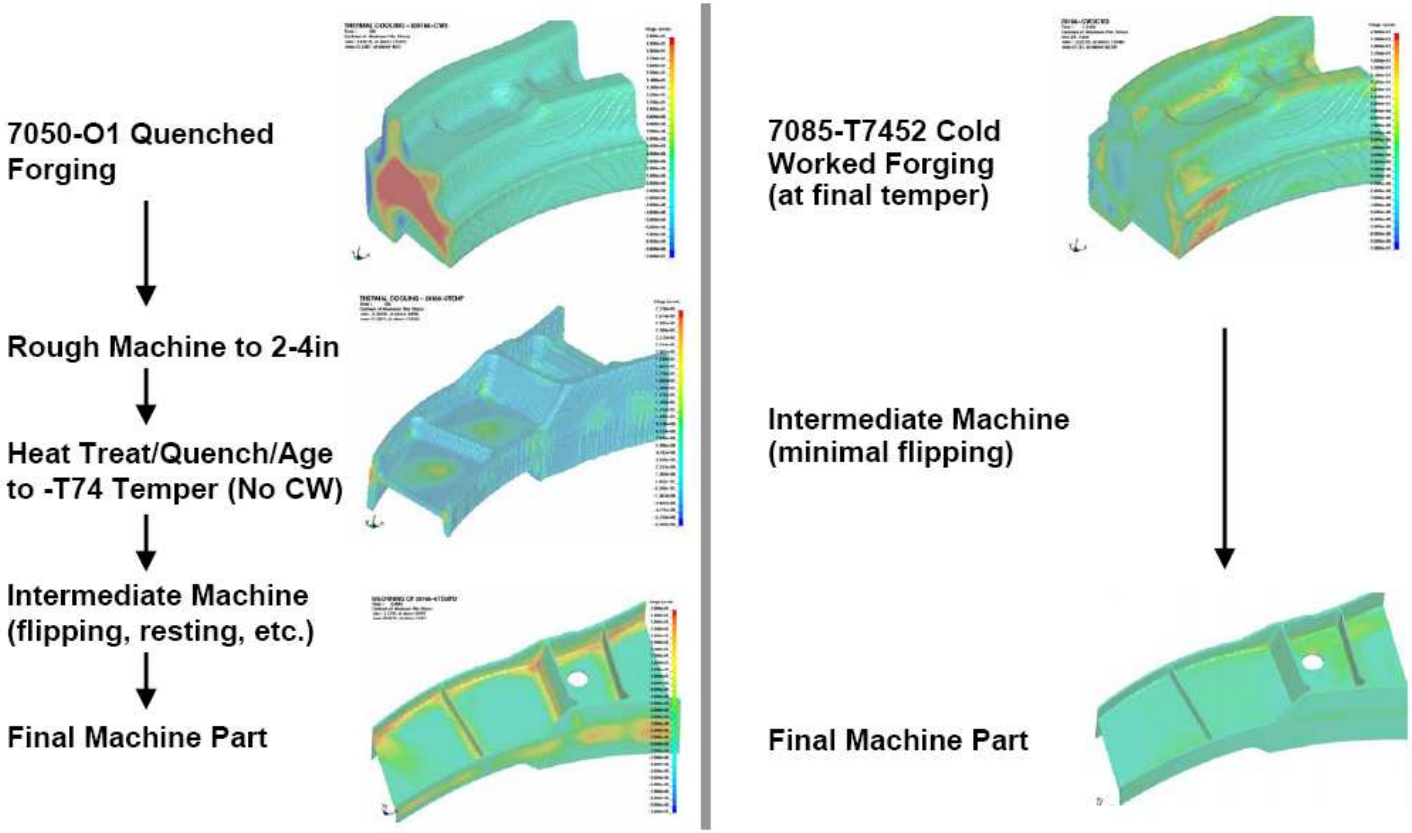
- Consider forging process
  - Geometrical tolerances obtained by subsequent machining/milling

- Example applications

# Metals

## Forging

- Example of formation of residual stresses



# Composites

What are composite properties you can use to manufacture composite parts?

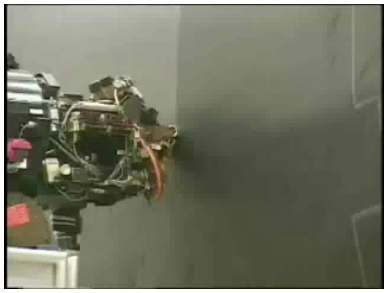
Composites consist of fibres and resin/polymer
Fibers (long): hardly elongate; you have to place them
*What about short fibers?*

Resin:
Thermoplastic: you can soften the polymer by heating
Thermoset: the resin is a liquid before curing

# Composites

## Categories of manufacturing processes

- Placement of fibres
  - Dry condition
  - Wet condition
  - Pre-impregnated



# Composites

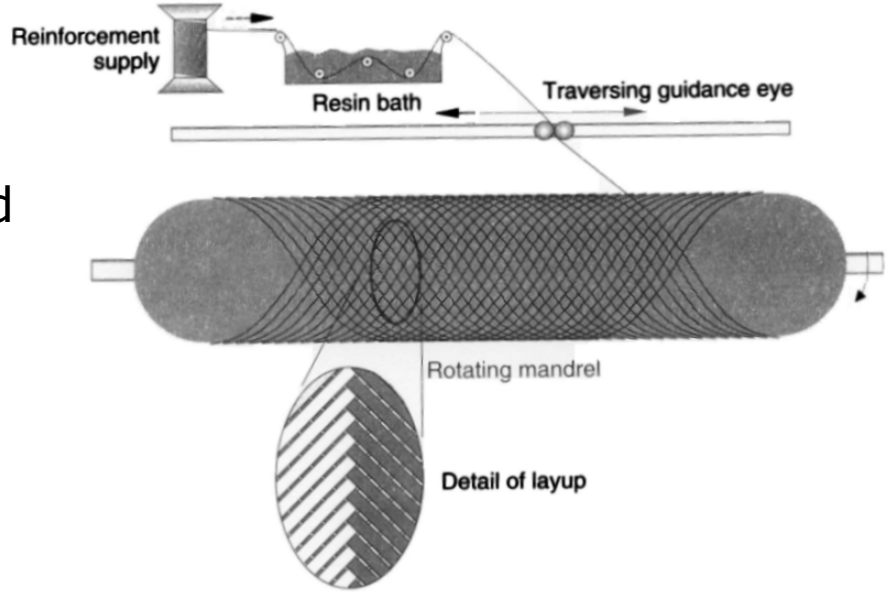
## Filament winding

- Typical product
  - Pressure vessel
  - Textile appearance

# Composites

## Filament winding

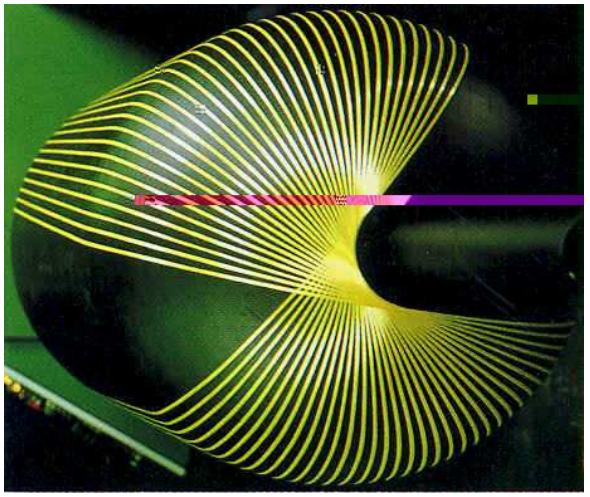
- Placement of fibres
  - Bound by initial orientation and friction
  - No free variable orientation possible
- Mould called MANDREL
  - Removable $\Rightarrow$ Solvable, collapsable, tapered
  - Used as liner $\Rightarrow$ Air-water tight
- Shapes
  - Closed shapes (cylinder like)
  - No open shapes (bathtub like)

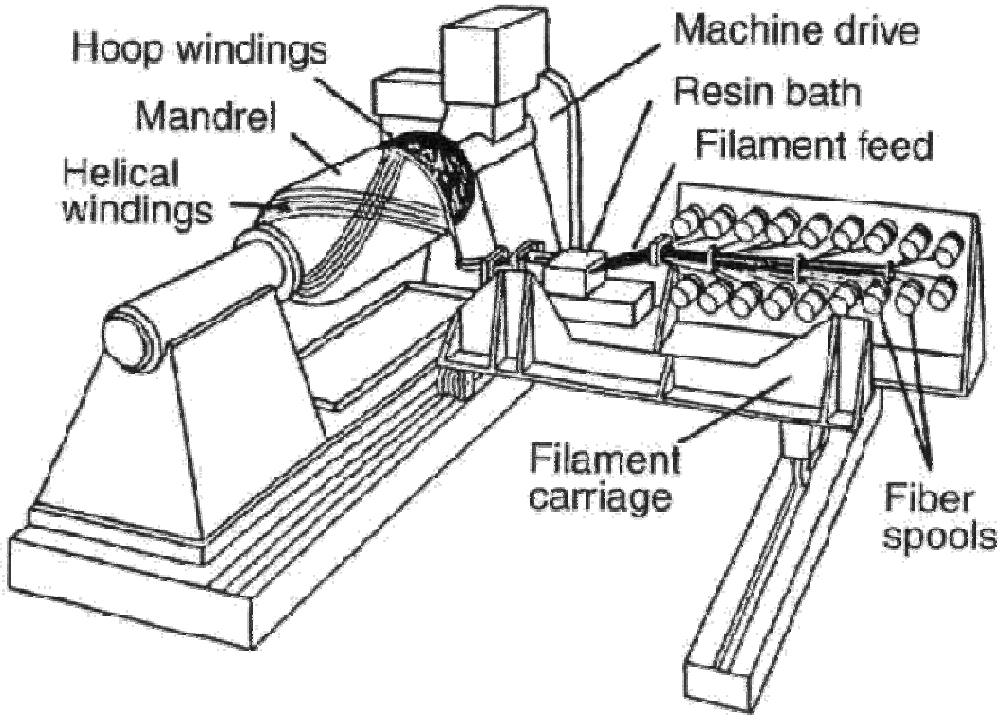


# Composites

## Filament winding

- Windings:
  - Hoop $\alpha_i = 90°$
  - Helical $\alpha_i = \pm n°$
  - Polar $\alpha_i \approx 0°$





# Composites

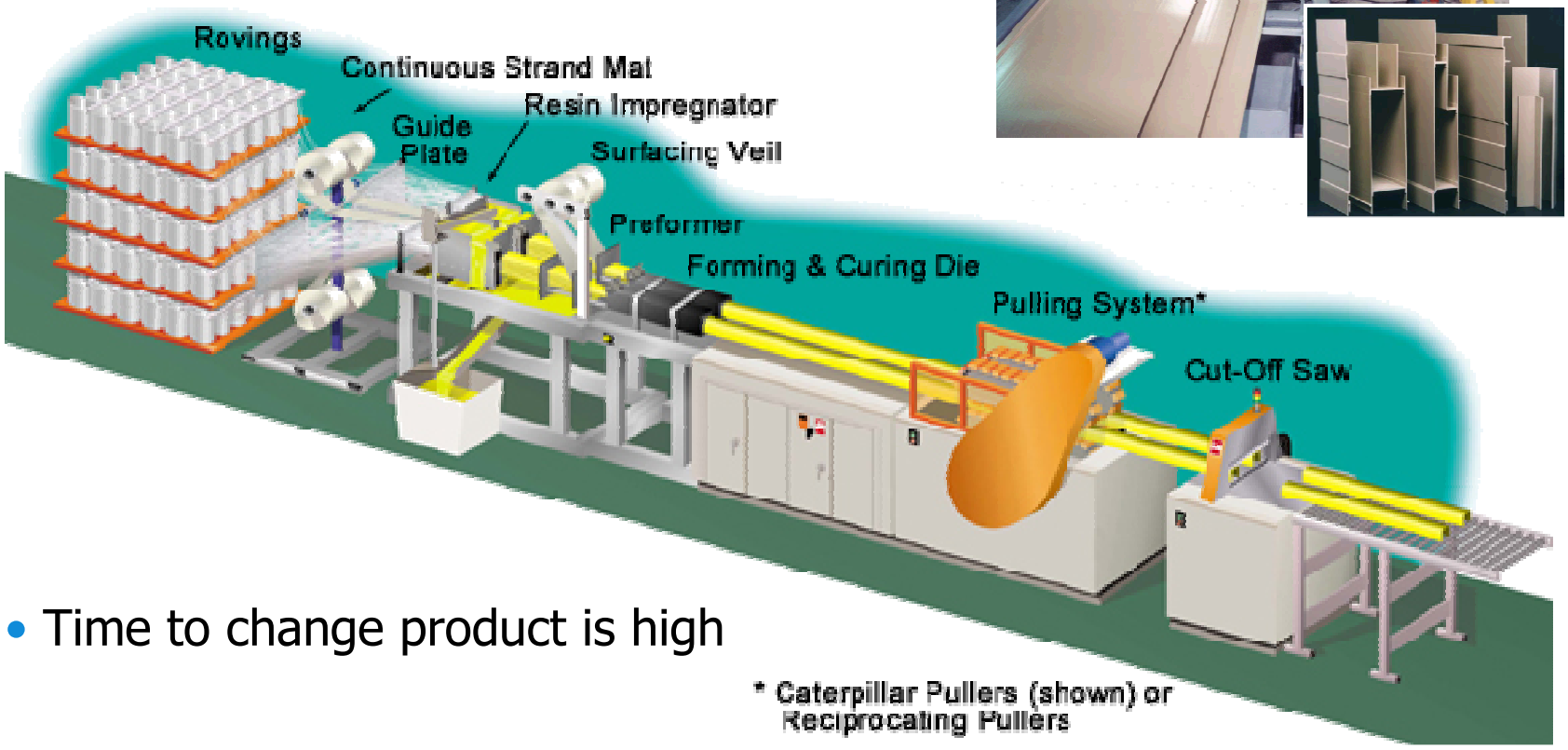
## Pultrusion

- Reinforcement:
  - Roving - Strand - UD material ⇐ most seen
  - Chopped strand (fibre mat)
  - Woven
- Matrix:
  - Thermoset: e.g. Polyesters, vinyl esters
- How to get the fibre material loaded

# Composites

## Pultrusion

- Machine

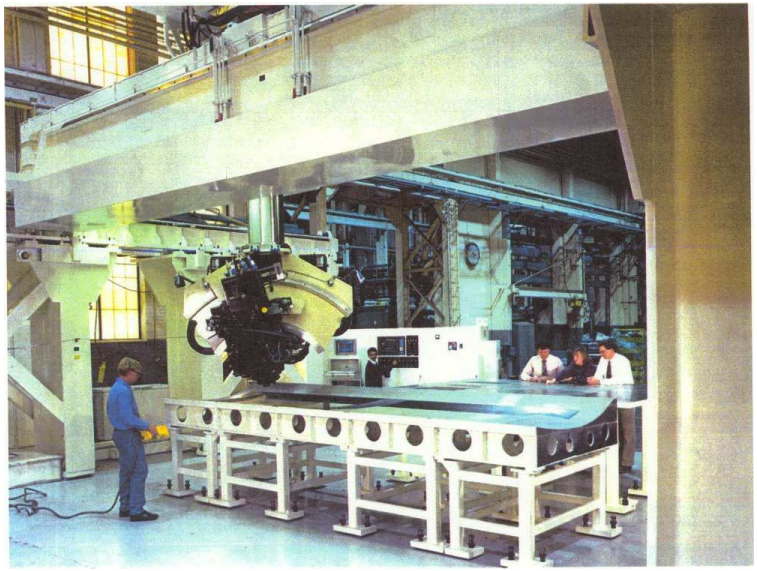



- Time to change product is high

# Composites

## Lay-up

- Lay-up by hand = Hand Lay-up
- Lay-up by machine = Tape Laying



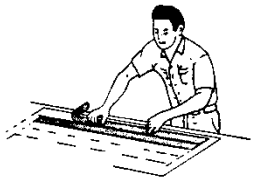
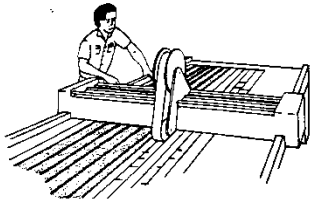
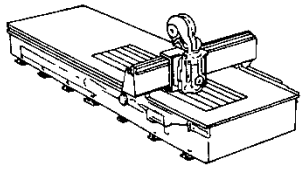
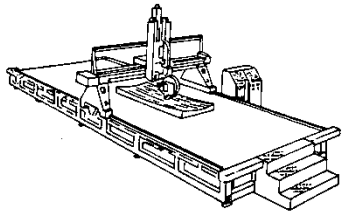
# Composites

## Lay-up

- Lay-up by machine = Tape Laying

# Composites

## Lay-up

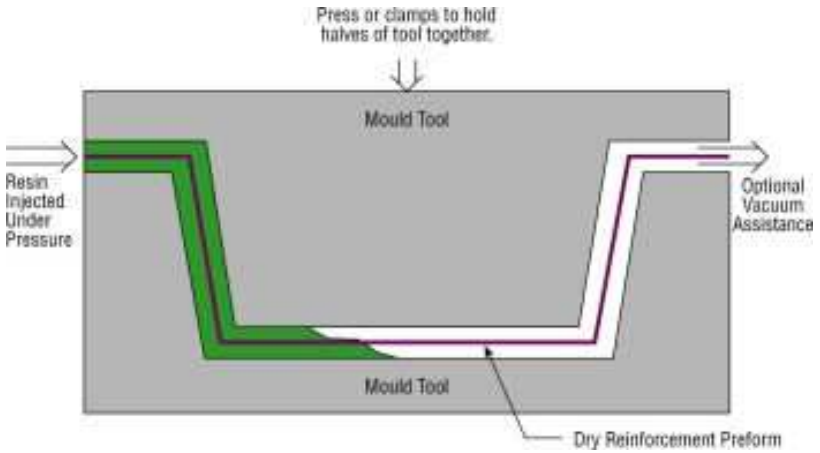





- Tape laying vs. Hand lay-up
  - More accurate lay-up
  - Better mechanical properties
  - Less differences between identical parts
  - More expensive
  - Often used for high end products, e.g. space technology
- Size can be large, limited by
  - Time needed for impregnation-curing
  - Autoclave size (possibly)
- Dry lay-up is followed by impregnation & curing
- Wet lay-up is followed by curing

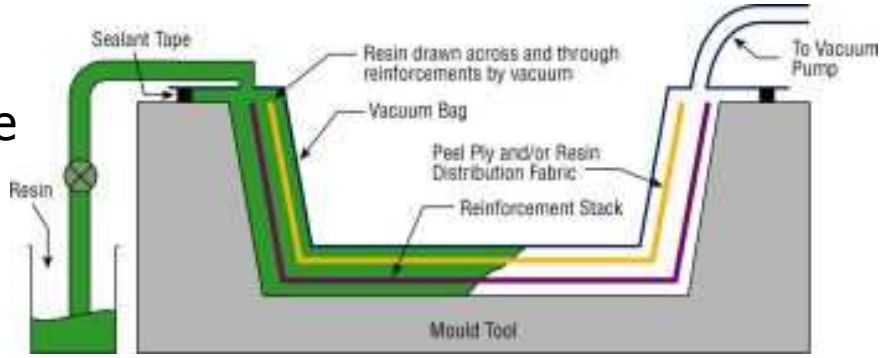
# Composites

## Resin Transfer Moulding (RTM)

- Resin Transfer Moulding (RTM)
  - Place dry fibres in stiff mould
  - Close mould system
  - Use pressure difference to draw resin through mould cavity



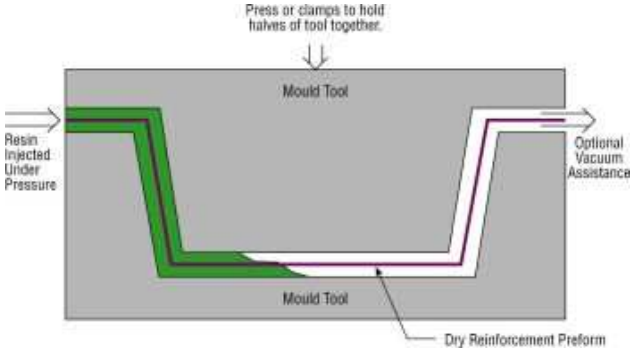

- Vacuum Infusion
  - Place dry fibres on stiff mould
  - Close mould with flexible film
  - Use vacuum to compress laminate and to draw resin through reinforcement

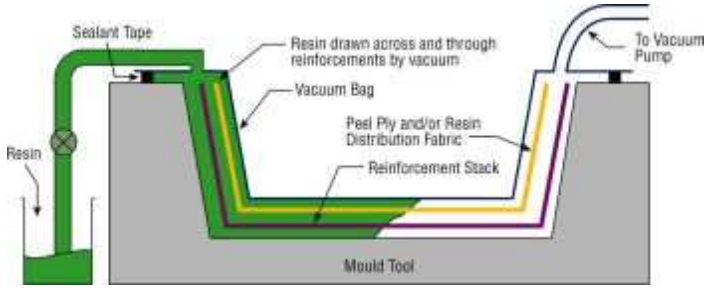


# Composites

## Resin Transfer Moulding (RTM)

- Resin Transfer Moulding (RTM)
  - Pressure injection: $P_1$>1bar, $P_2$=1bar
- Vacuum Assisted Resin Transfer Moulding (VARTM)
  - Pressure difference: $P_1$>1bar, $P_2$<1bar
- Vacuum Infusion
  - Pressure difference: $P_1$=1bar, $P_2$<1bar :



# Composites

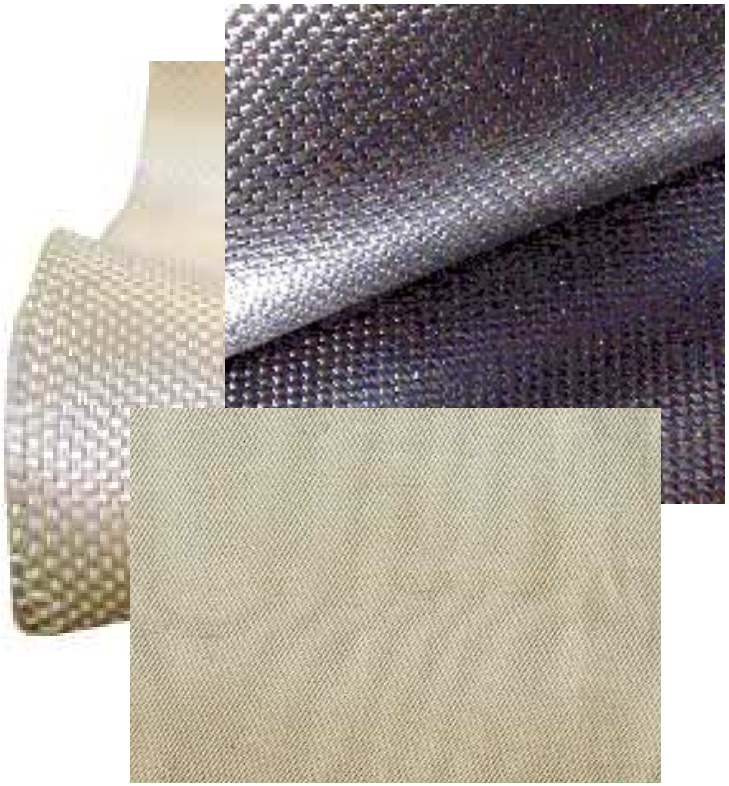
## Vacuum infusion

- Examples
  - Contest 55

  - Eaglet rudder


# Composites

## Thermoplastic vs. Thermoset



**A - Thermoset resin:**

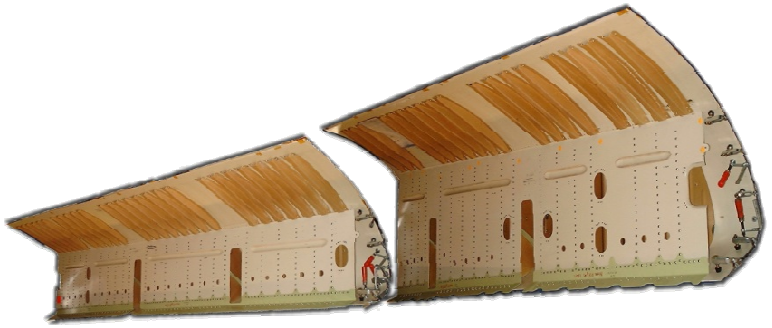
a) Liquid component A + liquid component B
b) Impregnate fibers
c) Chemical reaction
d) Solid matrix

**B - Thermoplastic resin:**

a) Solid matrix
b) Melting step
c) Impregnate fibers/press form part
d) Cooling step
e) Solid matrix

# Composites

## Thermoplastic vs. Thermoset



- Thermoplastic composites:
  - Rapid manufacturing
  - Recyclable
  - Weldable
  - High temperatures and pressures

- However:
  - Melt processing limits achievable thickness
  - Wind turbine blades are too large for pressing

- Melt processing of thermoplastic composites not suitable for manufacturing of wind turbine blades

# Summary

Manufacturing is strongly related to material properties
Type of products (shape) depends on materials and their processes

Metals

- Plastic deformation, melting, cutting
- Forming, casting and machining processes

Composites

- Two different components: resin & fibers
- Resin: thermoplastic or thermoset
- Fibers: almost no deformation, placing, orienting, drifting