

# Lecture 5. Non-metallic materials and manufacturing processes

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1 ***Plastics***

2 ***Ceramics***

3 ***Additive  
Manufacturing***

4 ***Composites***

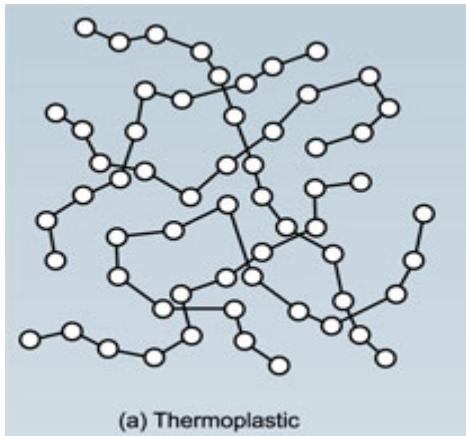
## **Plastics**

- **Ceramics**
- **Additive Manufacturing**
- **Composites**

*Compression moulding  
Injection moulding  
Blow moulding  
Thermoforming  
...*

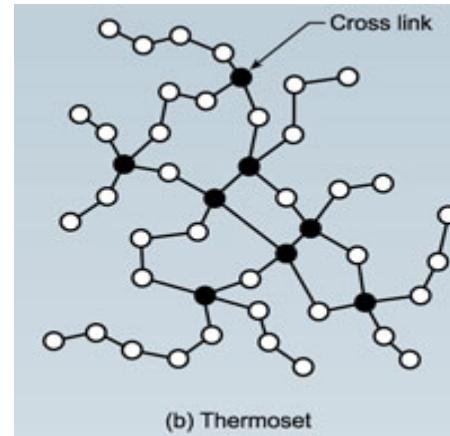
# Plastic materials

- ***Thermoplastic***



**Ductile  
Low modulus  
and strength  
Recyclable  
Fast processing**

- ***Thermoset***



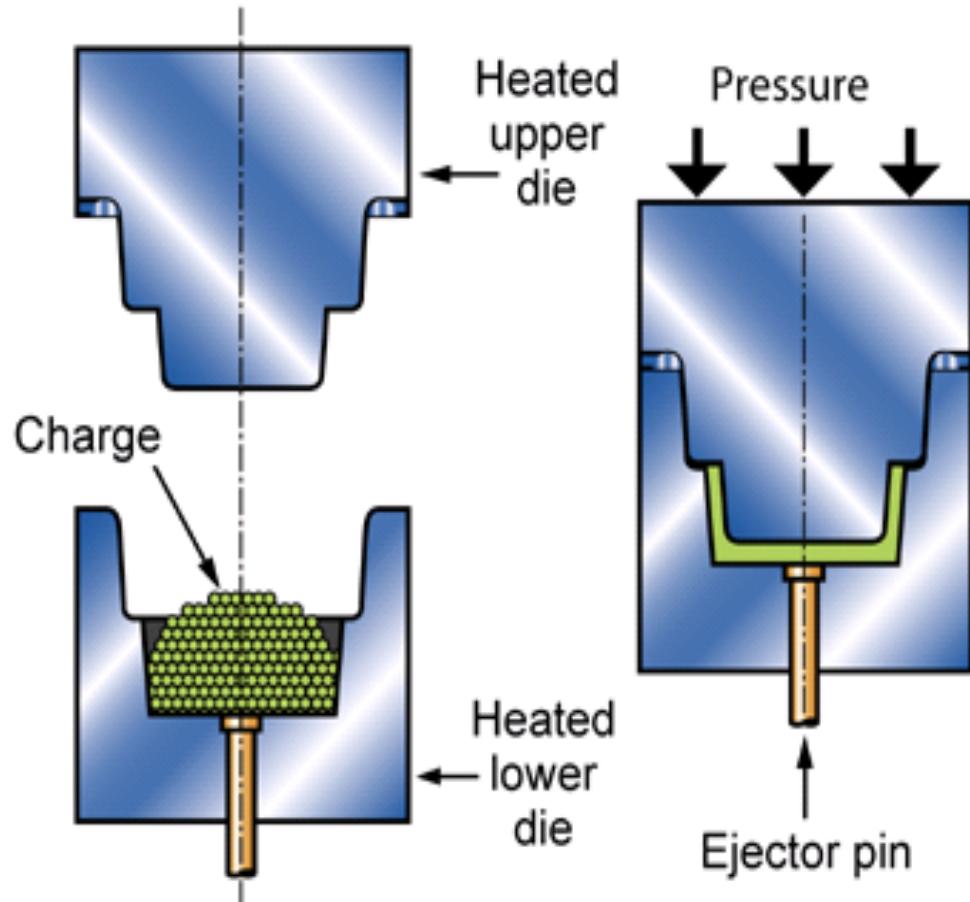
**Brittle  
High modulus  
and strength  
Non-recyclable  
Slow processing**

- A thermoplastic material softens (becomes pliable and plastic) when heated, but it does not cure or set.
- It becomes softer and more fluid as heat increases. As it cools, it will harden in the shape of the mould, but there is no chemical curing at work.

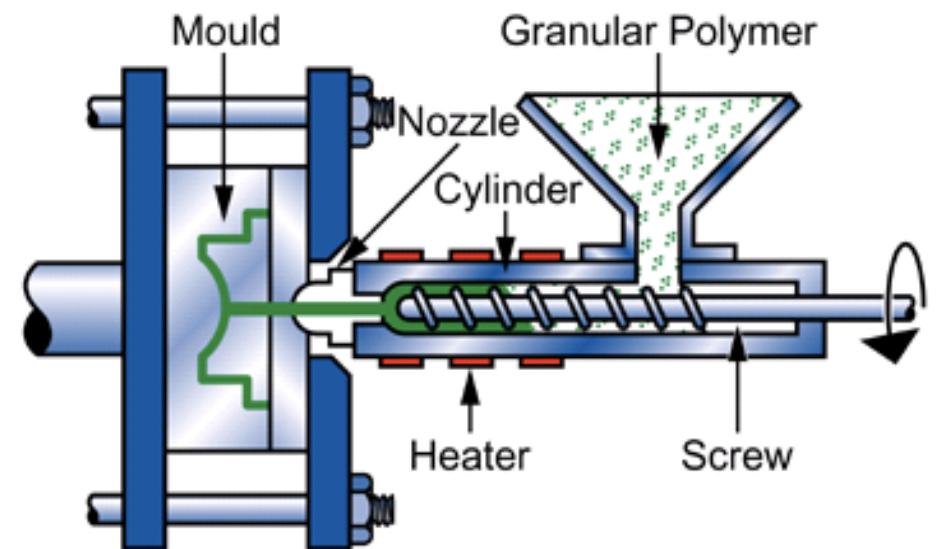
As the name suggests, a thermoset is a material (such as rubber) that cures or hardens (sets) into a given shape, generally through the application of heat (a thermal increase). Curing (also referred to as vulcanizing) is an irreversible chemical reaction.

# Plastics

- ***Compression moulding***



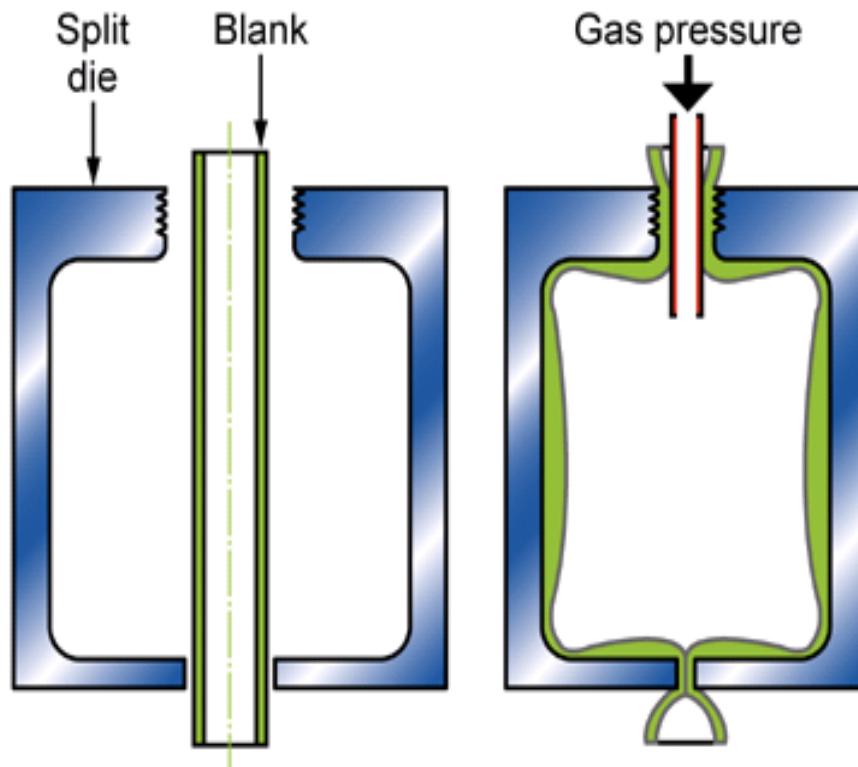
- ***Injection moulding***



Only for thermoplastics

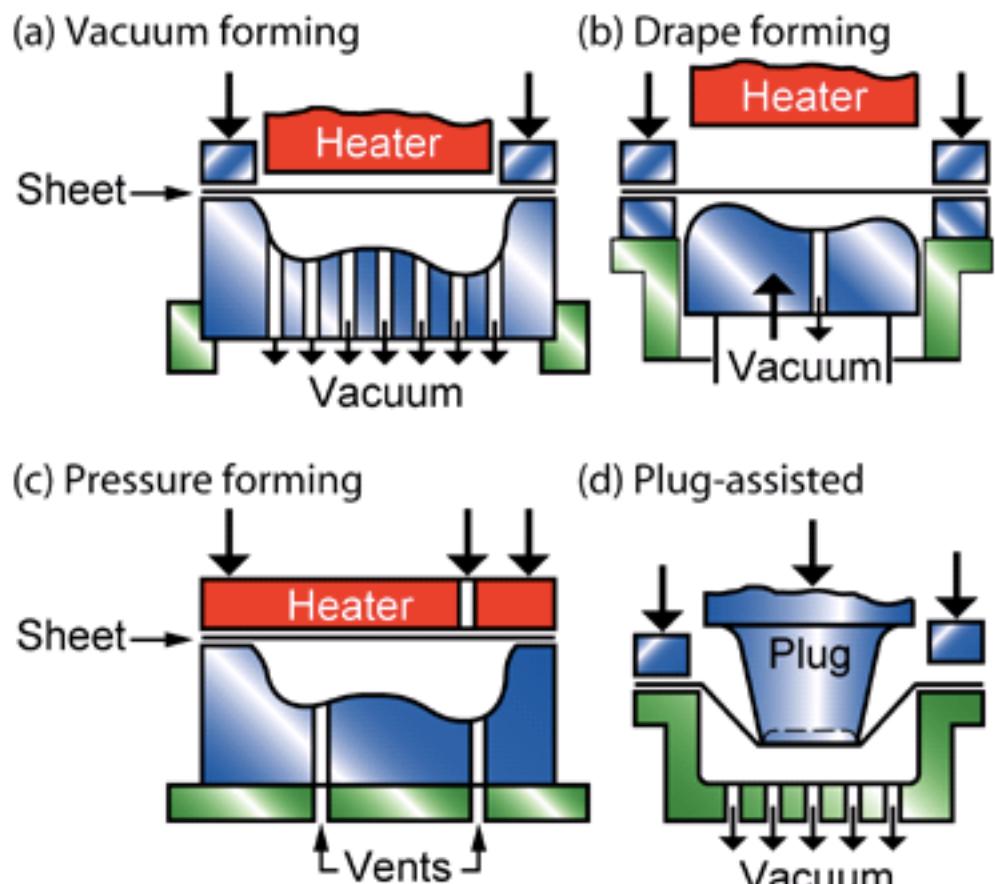
# Plastics

- ***Blow moulding***



Only for thermoplastics

- ***Thermoforming***



Only for thermoplastics

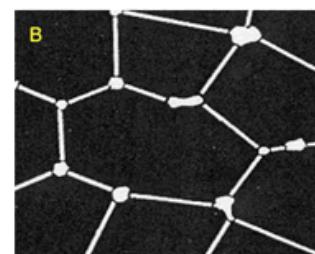
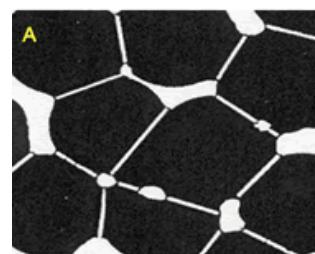
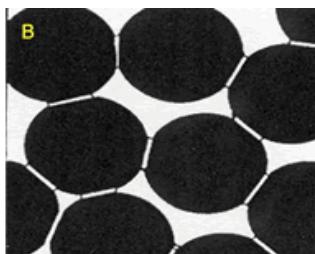
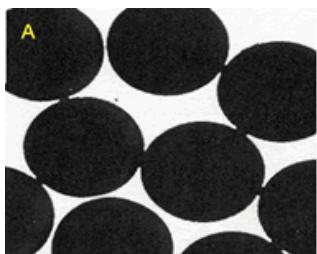
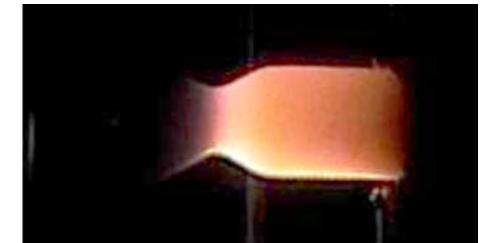
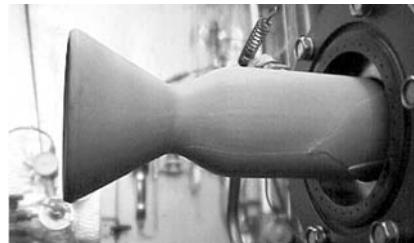
- **Plastics**
- **Ceramics**
- **Additive Manufacturing**
- **Composites**

*Die pressing & Sintering  
Tape casting*

...

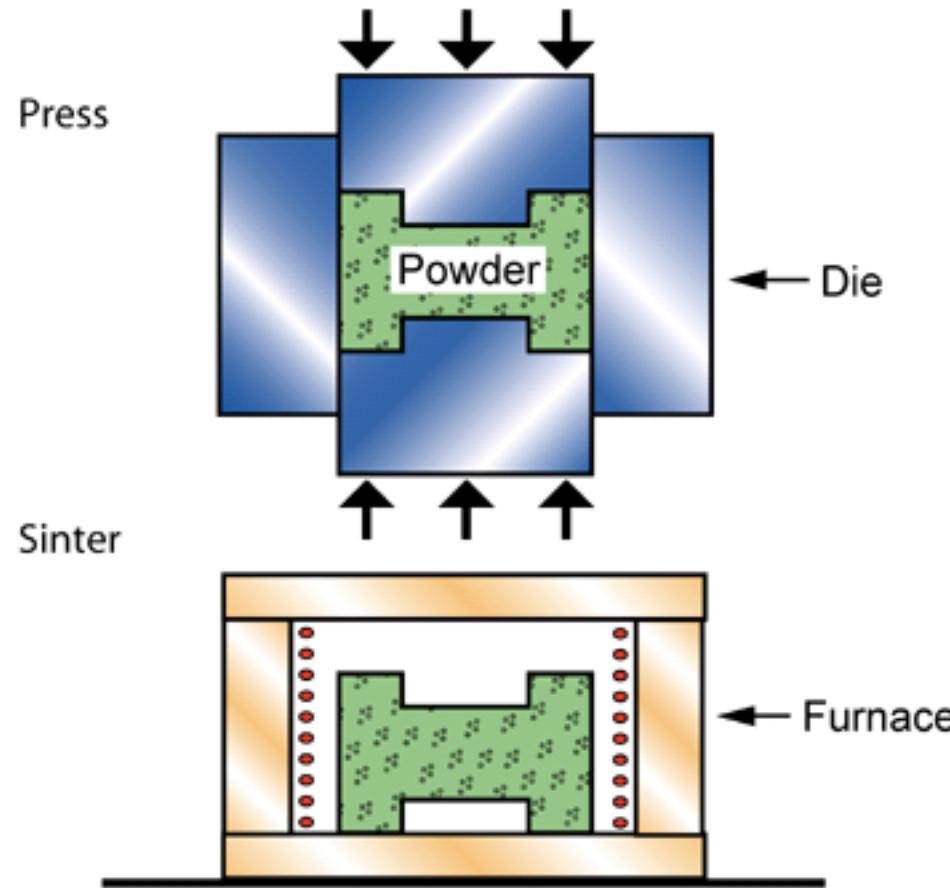
# Ceramics

- *High strength*
- *High service temperature*
- *High wear resistance*
- *Excellent heat and electrical insulator*
- *Brittleness*
- *Manufacturing method*
  - *Milling > Batching > Mixing > Forming > Drying > Firing*
- ***Green-body & Sintering*** (*applicable also for powder metallurgy*)

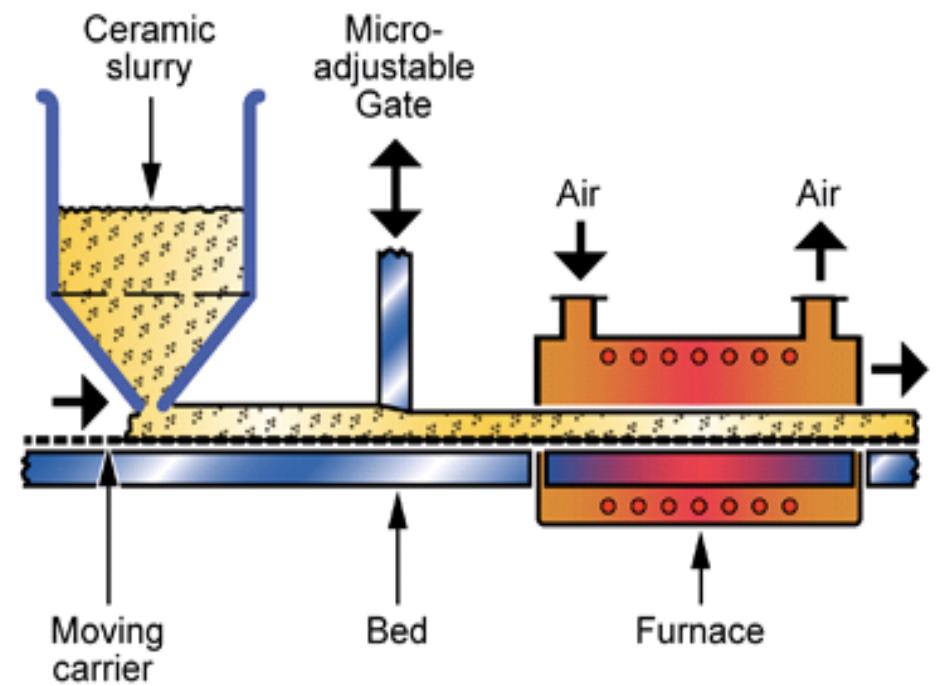


# Ceramics

- ***Die pressing & Sintering***



- ***Tape casting***



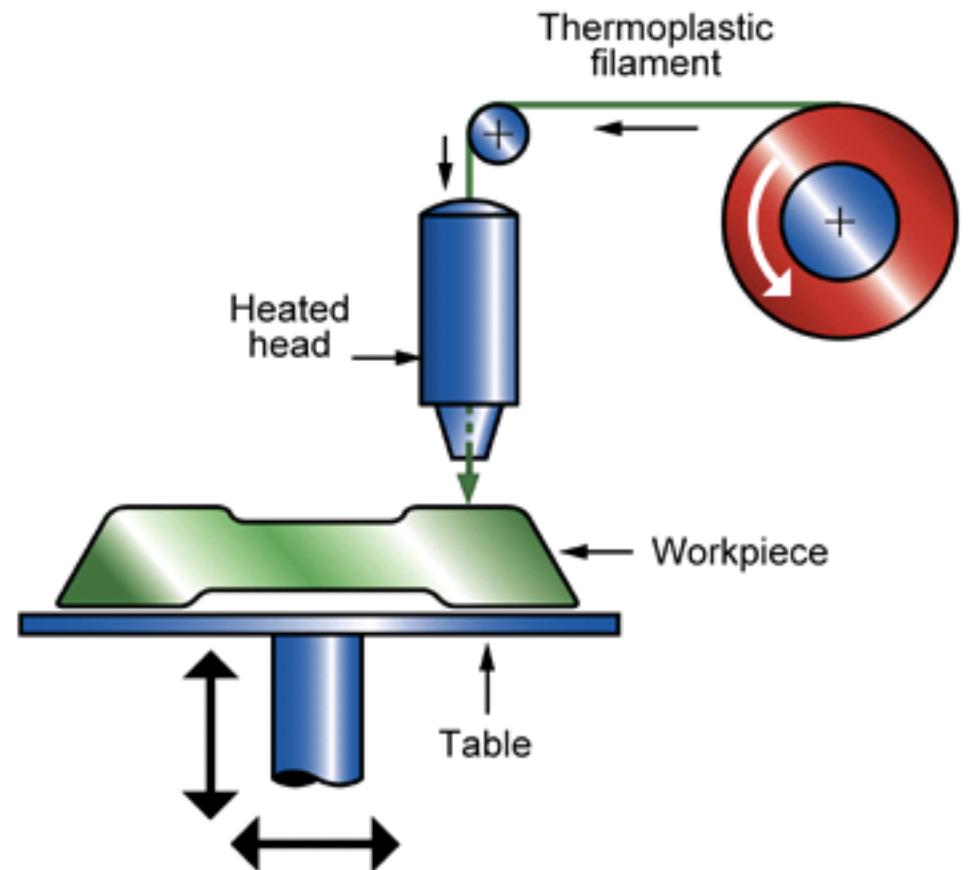
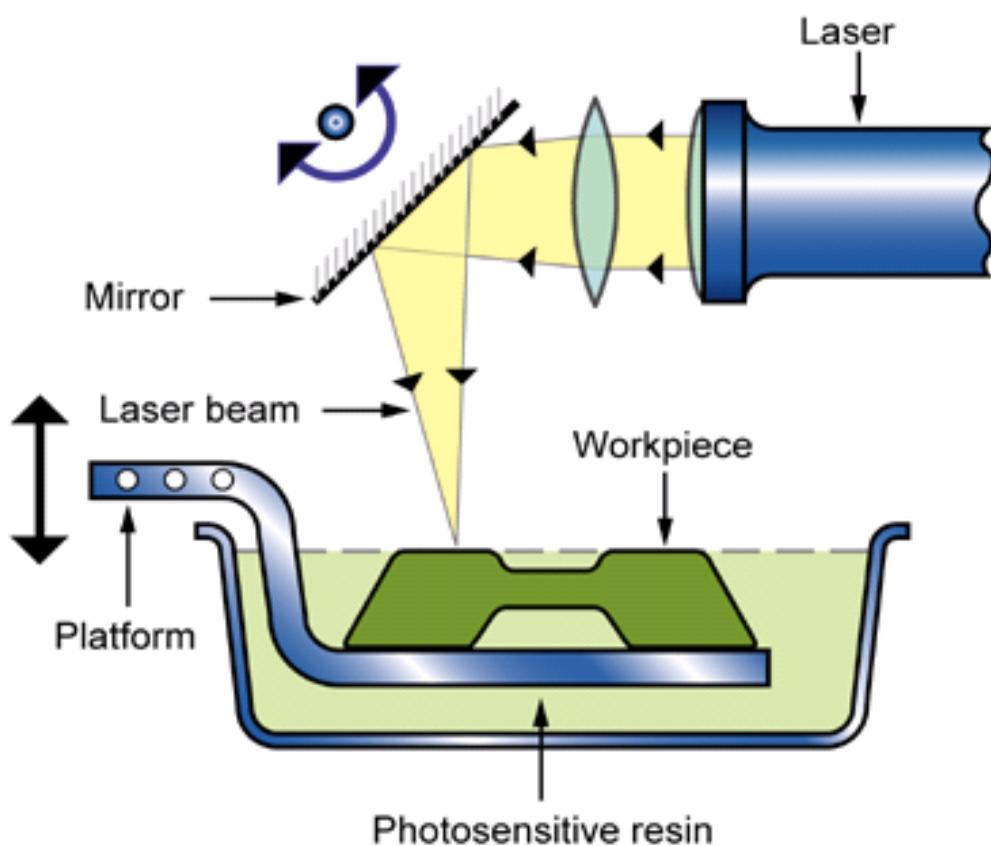
- **Plastics**
- **Ceramics**
- **Additive Manufacturing**
- **Composites**

*SLA (Stereolithography)  
FDM (Fused deposition modelling)*

...

# Additive manufacturing for non-metals

- **SLA (Stereolithography)**
- **FDM (Fused Deposition Modelling)**



# Additive manufacturing

- ***Ford 3D printing (Sand printing)***



- **Plastics**
- **Ceramics**
- **Additive Manufacturing**
- **Composites**

### *Material Deposition*

- *Hand & Spray layup*
- *Filament Winding*
- *Braiding*
- *AFP & ATL*

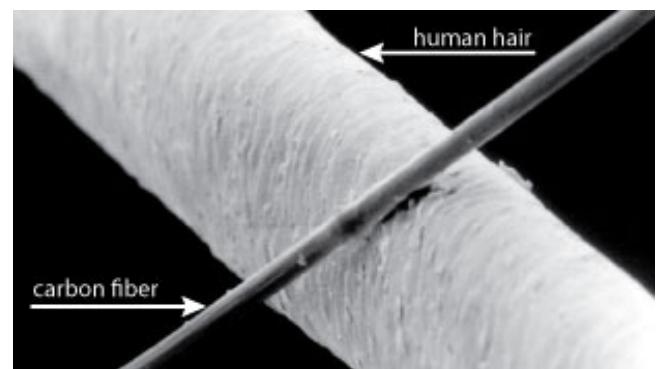
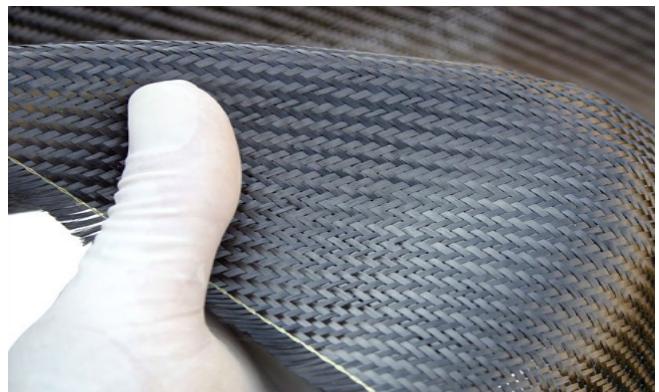
### *Curing Process*

- *Vacuum bag moulding*
- *Autoclave moulding*
- *RTM & VARTM*

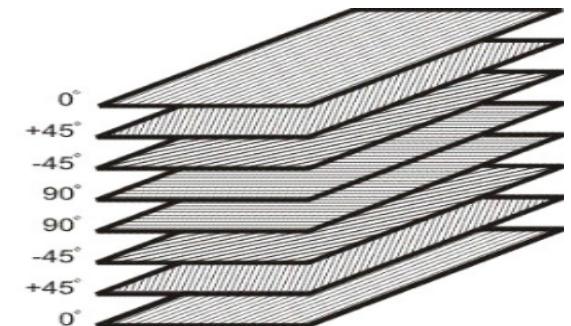
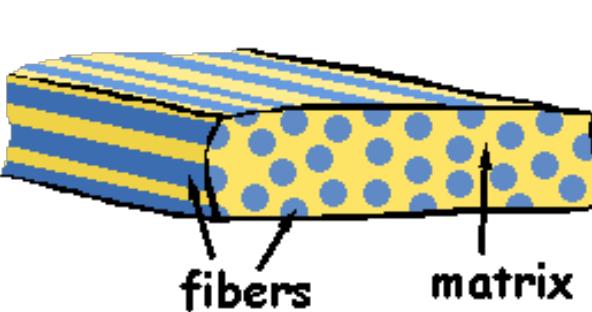
### *Pultrusion & Continuous laminating*

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# Composite materials



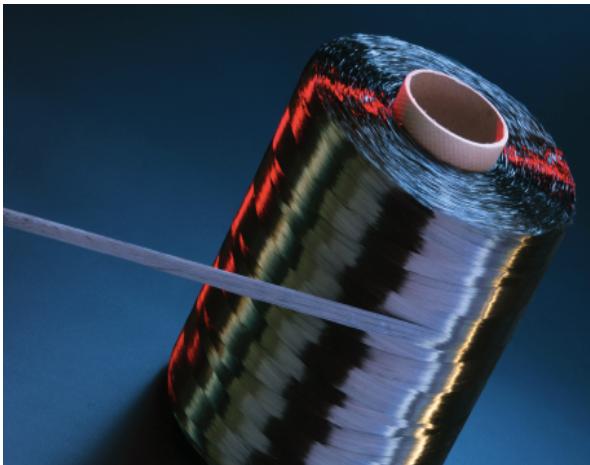
- *Lightweight*
- *High specific stiffness & strength*
- *Anisotropic material property*



- *Reinforcements*
  - Type: Continuous or discontinuous fibres
  - Materials: Carbon / Glass / Aramid fibres
- *Matrix*
  - Thermoset: Epoxy, Polyester, BMI
  - Thermoplastic: PEEK, PP, PVC

# Composite materials

Dry tow



Dry  
→  
Wet

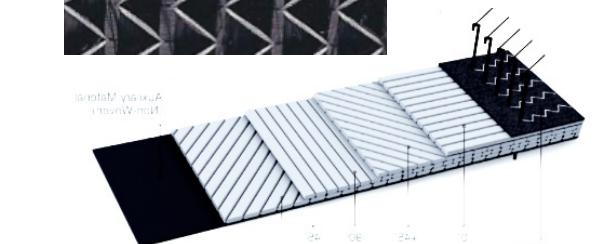
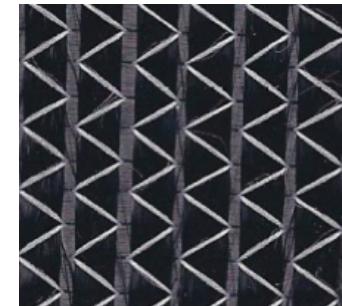
Fabric (Dry)



Prepreg  
(Pre-impregnated)

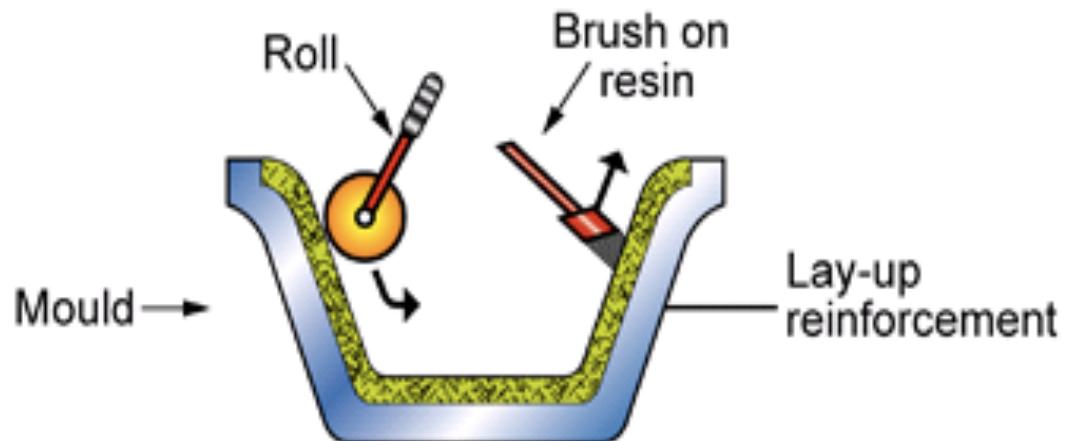


NCF (Non-Crimp  
Fabric, Stitched)

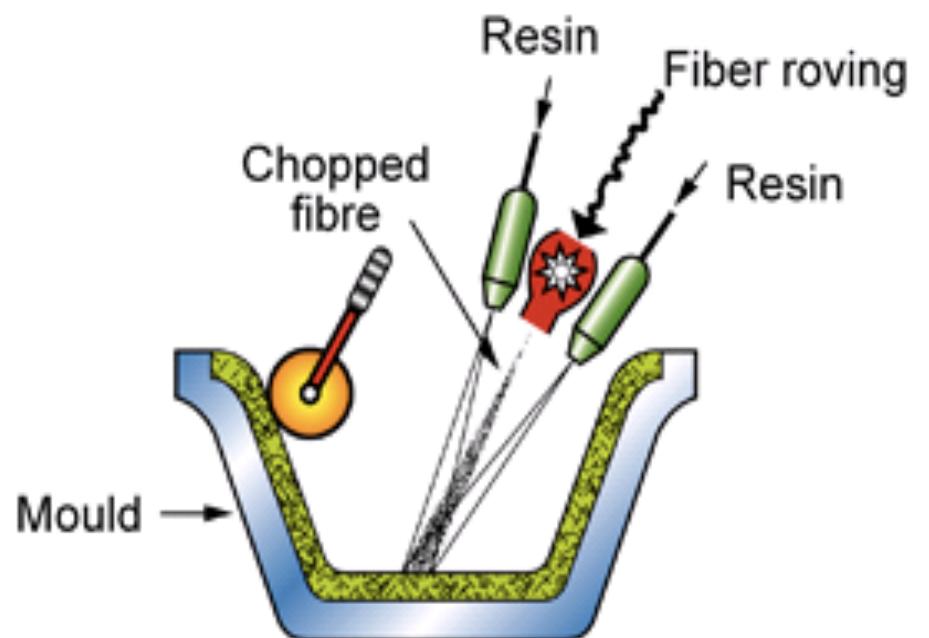


# Composites > Material deposition

- ***Hand layup***

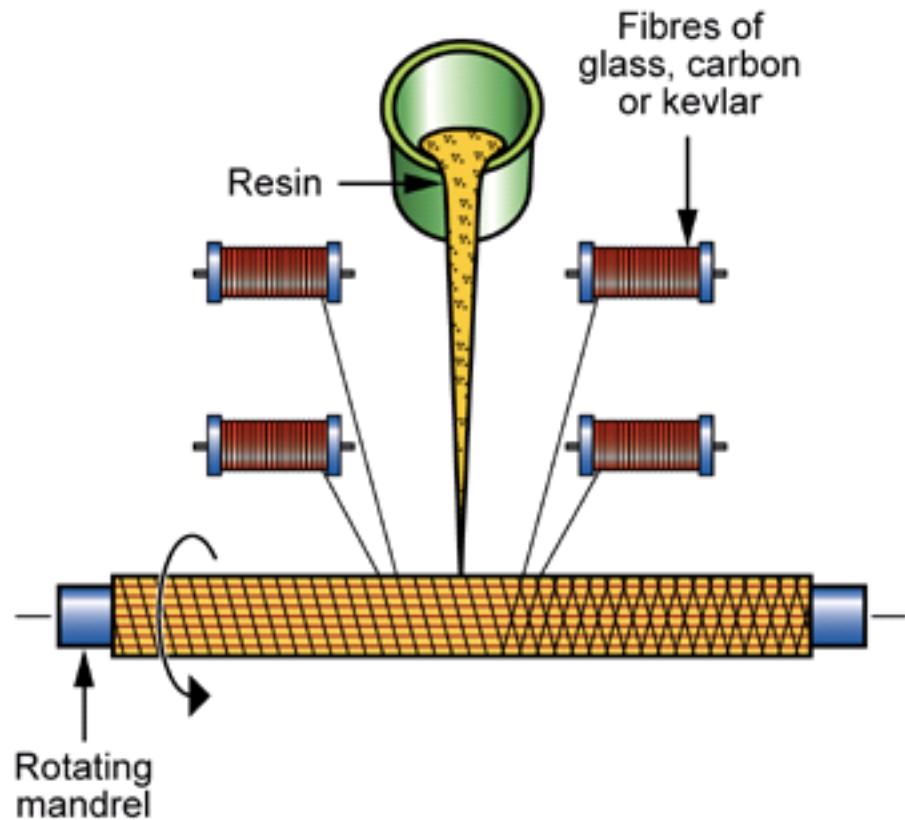


- ***Spray-up***

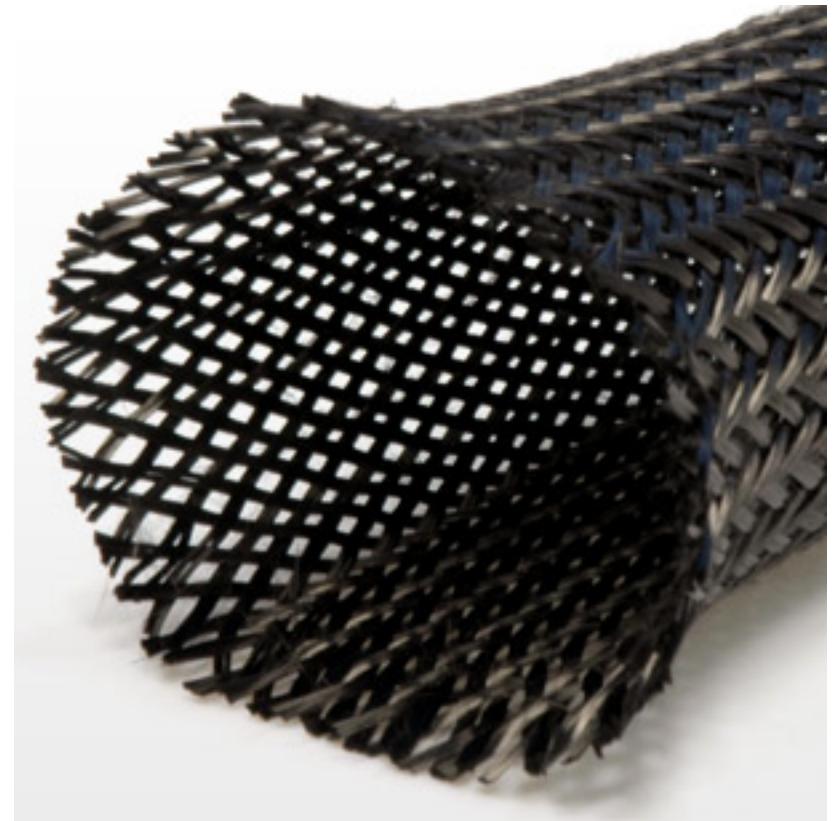


# Composites > Material deposition

- ***Filament winding***

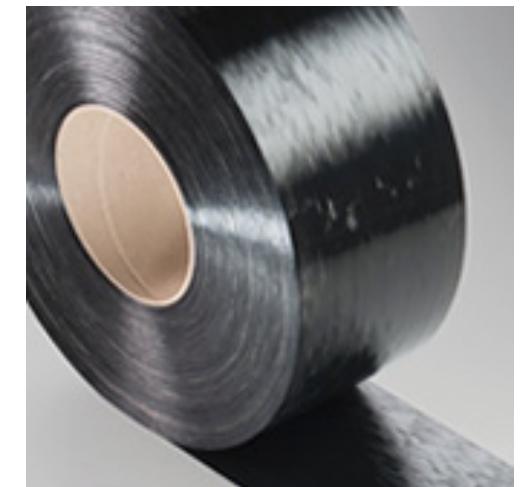
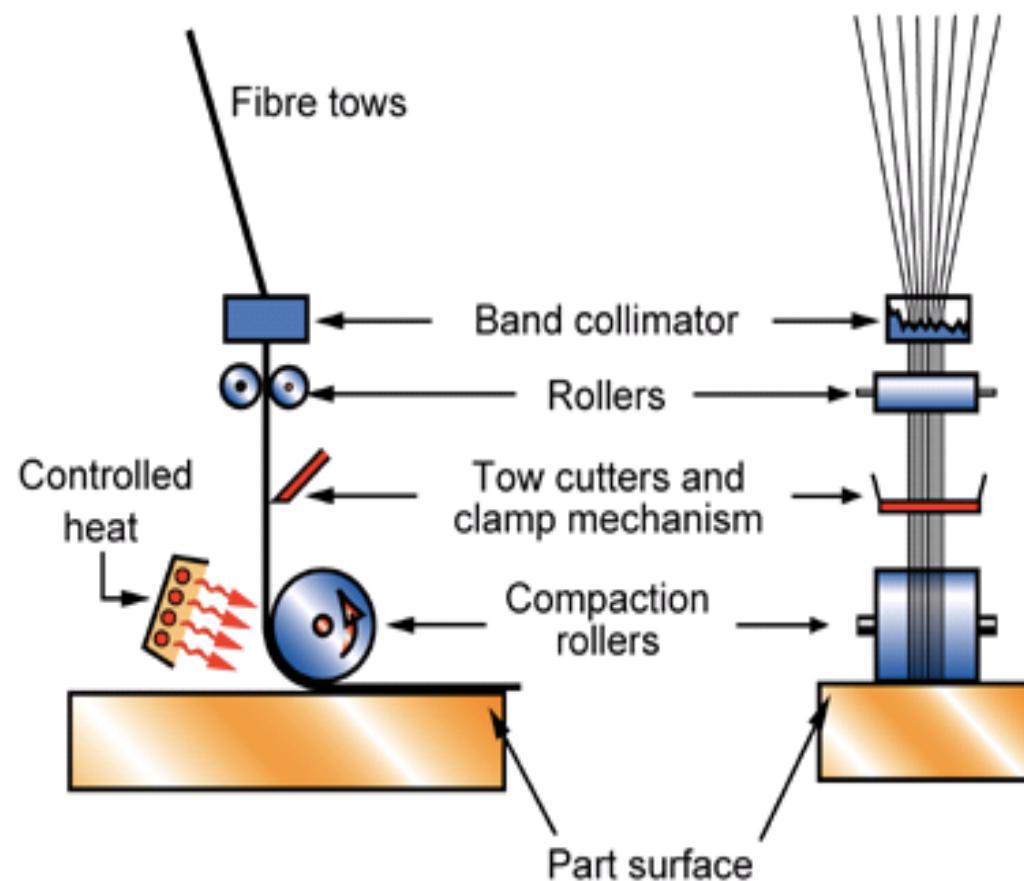


- ***Braiding***



# Composites > Material deposition

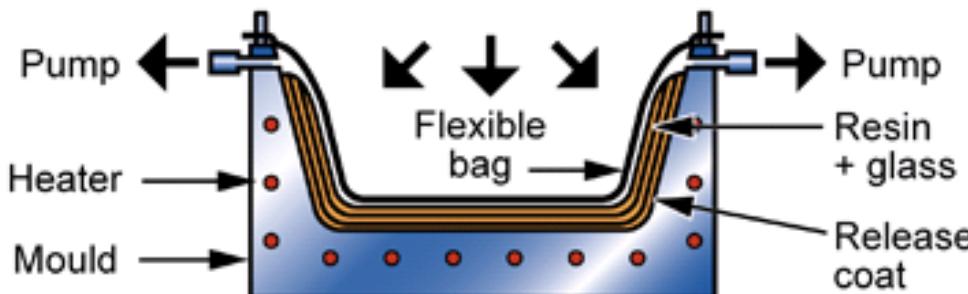
- **AFP (Automated Fibre Placement)**
- **ATL (Automated Tape Laying)**



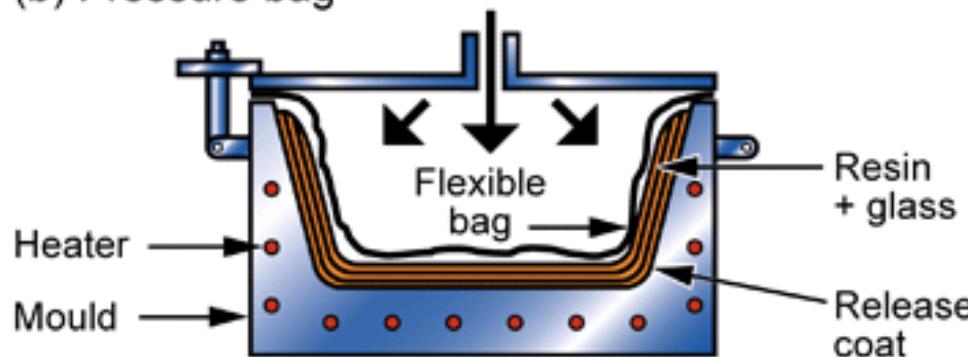
# Composites > Curing process

- ***Vacuum bag moulding***

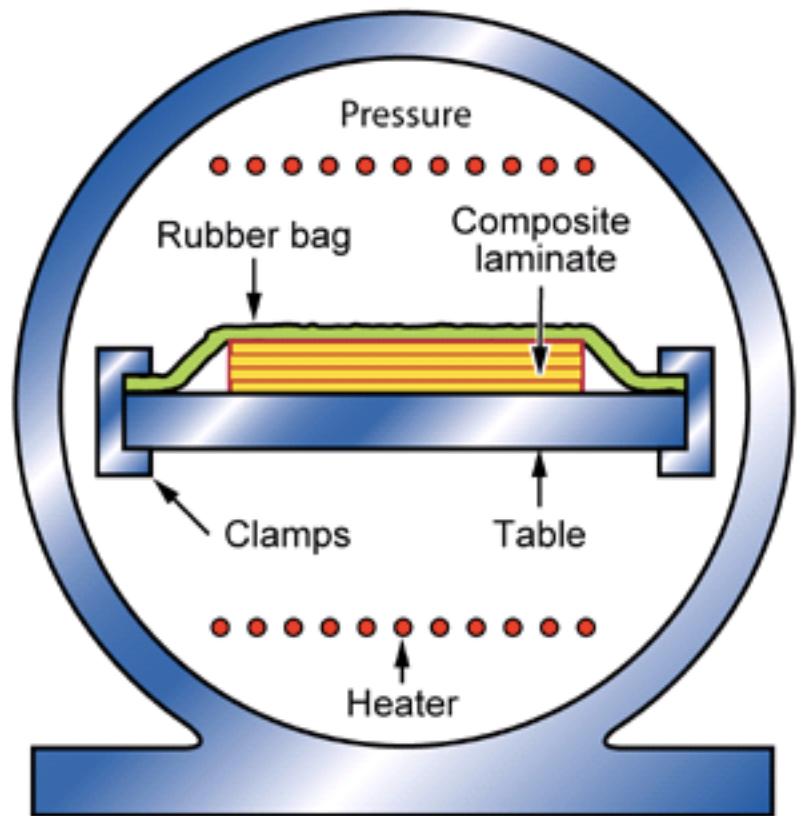
(a) Vacuum bag



(b) Pressure bag

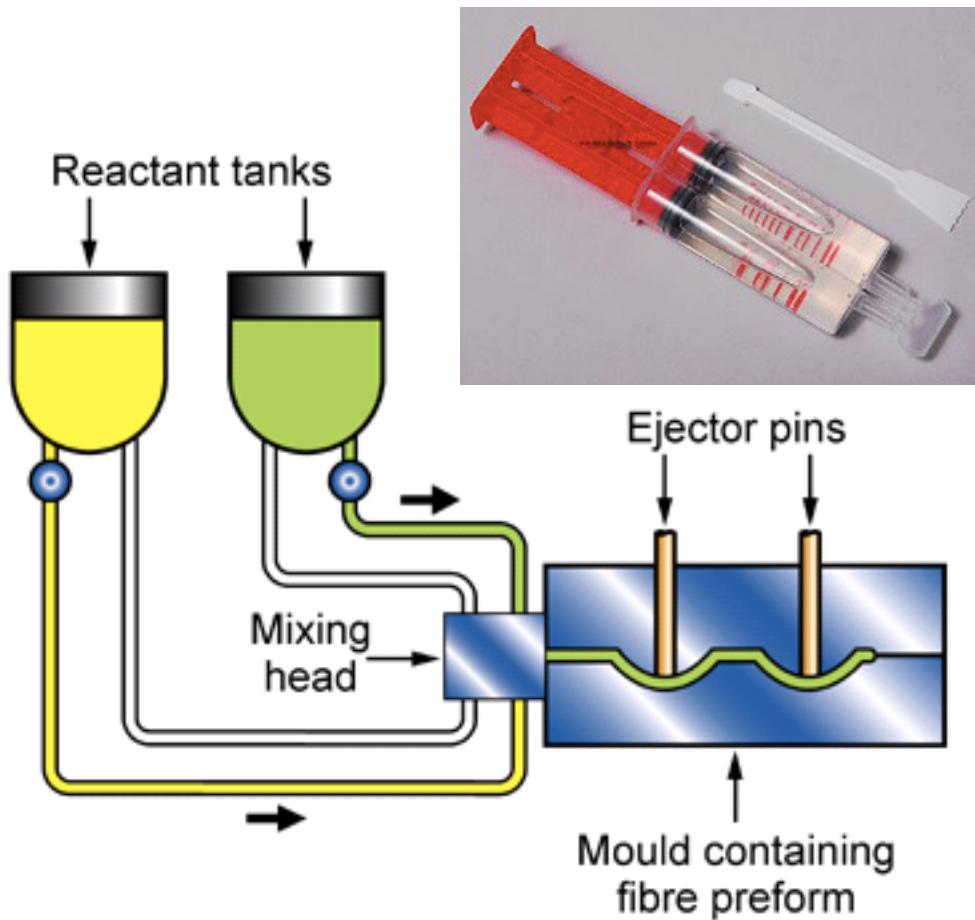


- ***Autoclave moulding***

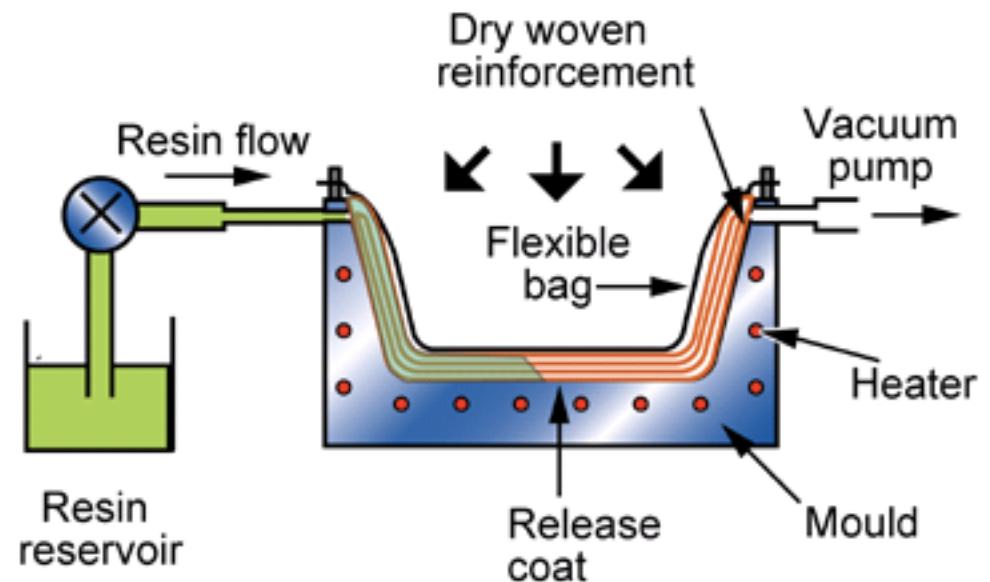


# Composites > Curing process

- **RTM (Resin Transfer Moulding)**

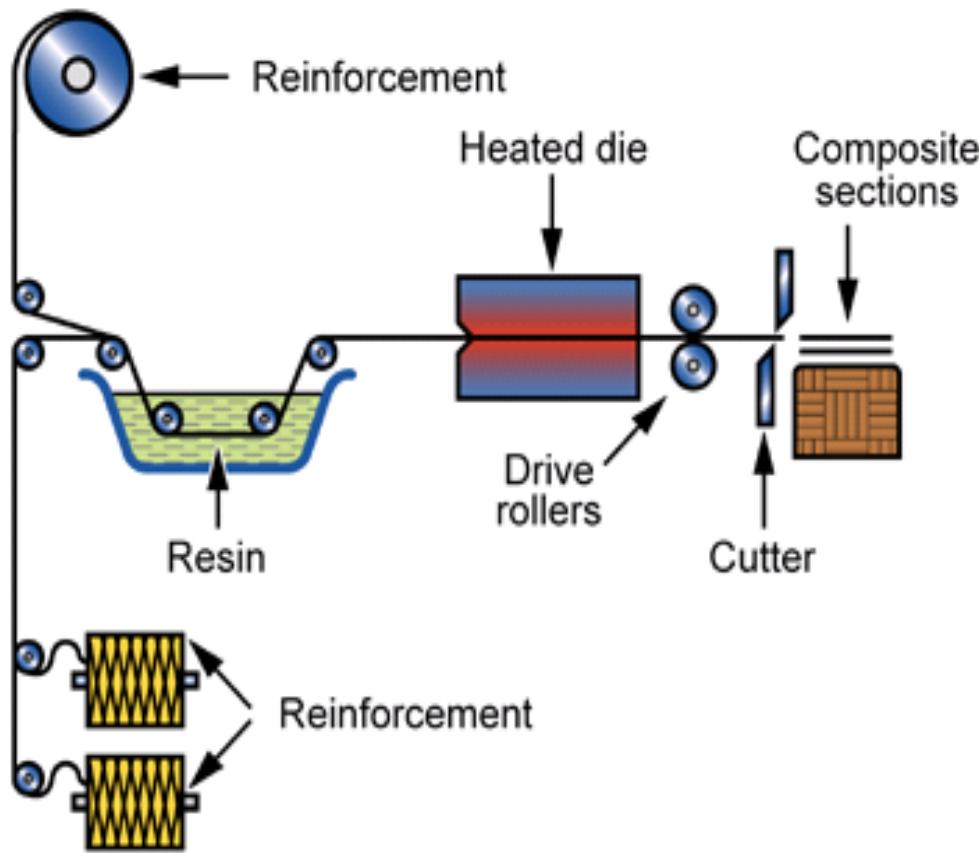


- **VARTM (Vacuum assisted resin transfer moulding)**

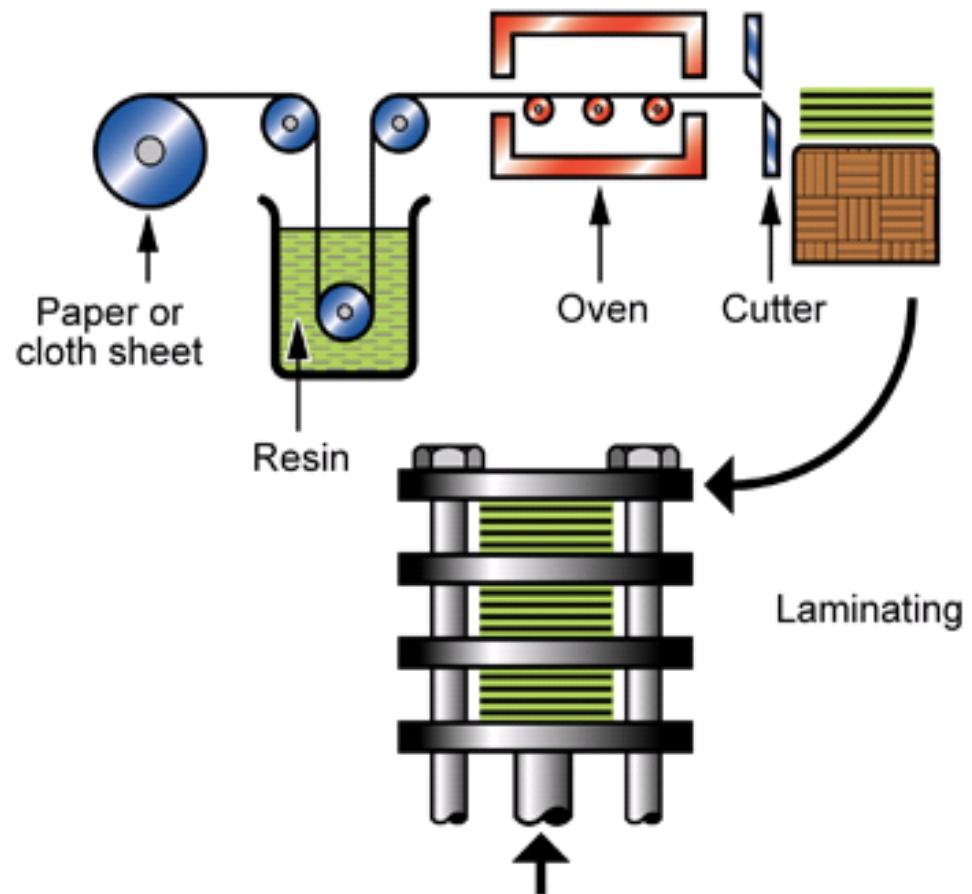


# Composites > Material deposition + Curing

- **Pultrusion**



- **Continuous laminating**



# Understanding manufacturing processes

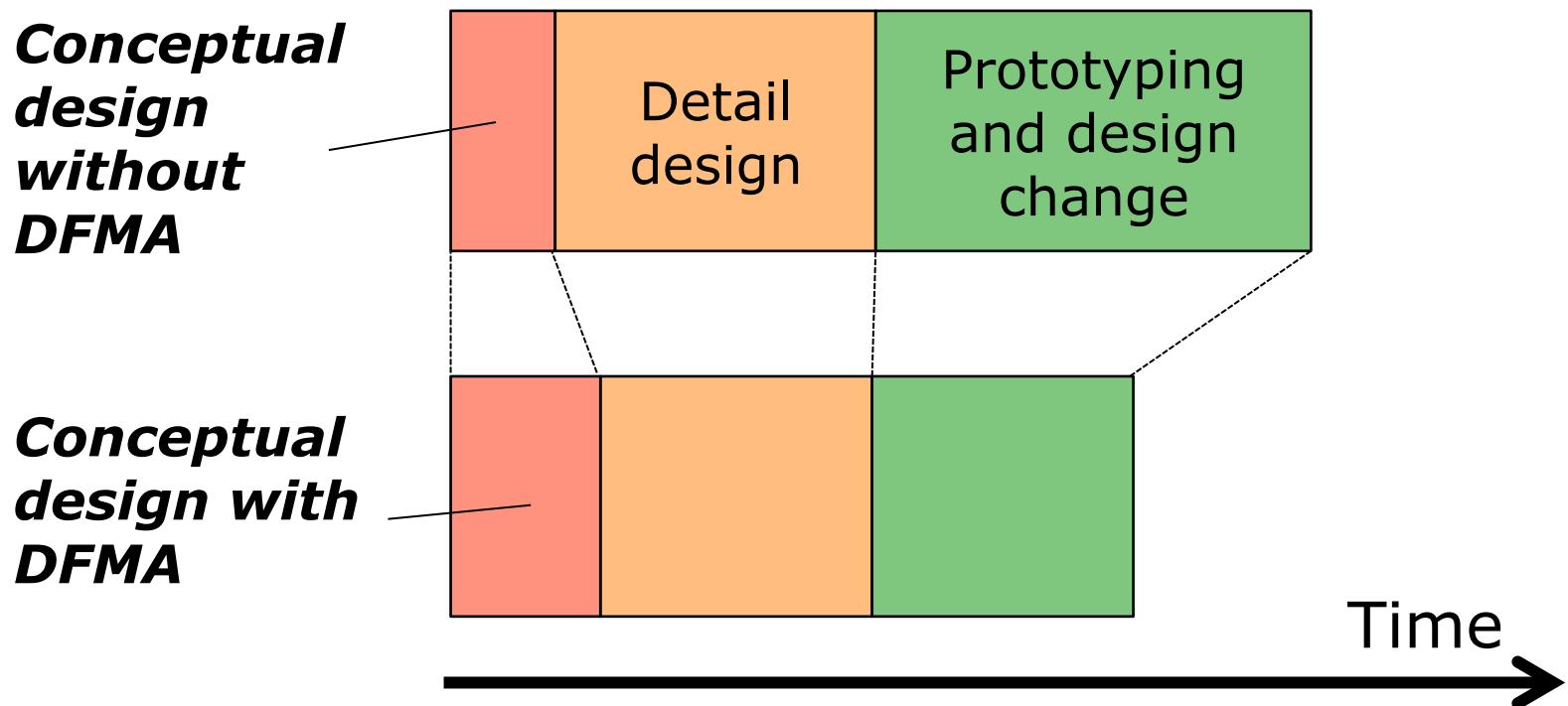
Simplified Sequence of Operations	
Raw material bar stock cylinder with flat ends	Cut bar stock to length; centerdrill ends.
Multiple cylinders made by turning (see Figure 1-12)	Turn (on a lathe); rough turn and finish turn.
External cylindrical Three external cylindrical surfaces and four flats	Turn (on a lathe) the smaller external cylindrical surfaces.
Flat Three cylinders and six flats	Mill the flat on the right end. Mill the slot on the left end.
Slot Four internal holes	Drill four holes on left end. Tap (internal threads) holes.

Ref. Degarmo's Materials and Processes in Manufacturing

- As you have learnt various manufacturing methods, you could plan how to make your product.
- However, you should ask yourself if your plan is the best way to make it in the design stage.
- The manufacturing process can affect:
  - Cost (Material & manufacturing)
  - Lead time and product price
  - Performance

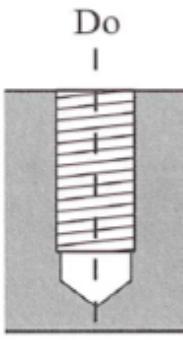
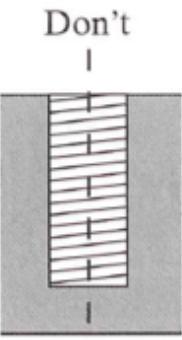
# Concurrent Engineering

- DFMA = DFM (Design for Manufacturing) + DFA (Design for Assembly)

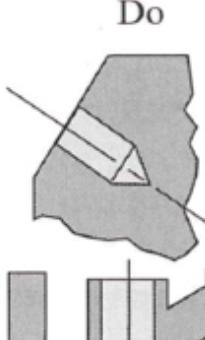


# DFM (Design for Manufacturing)

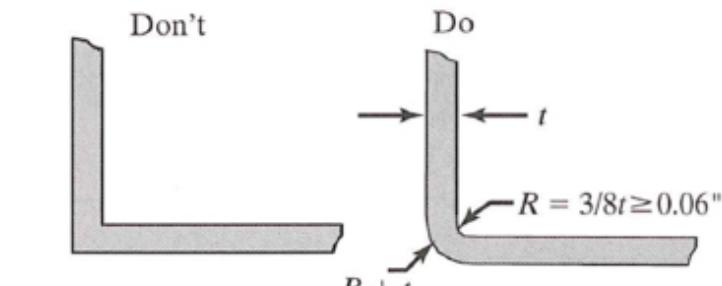
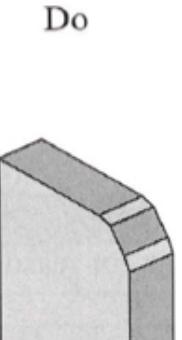
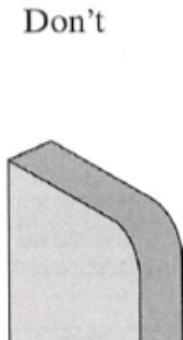
- You should be able to imagine how the parts can be manufactured, and reduce the manufacturing cost.



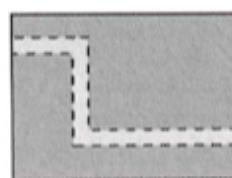
Design holes to the shape of tool. If hole is to be tapped, provide space for it.



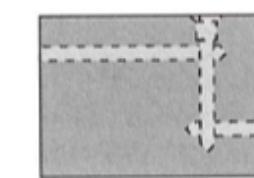
Avoid drilling inclined faces.



Avoid sharp corners, they produce stress concentrations and obstruct material flow.



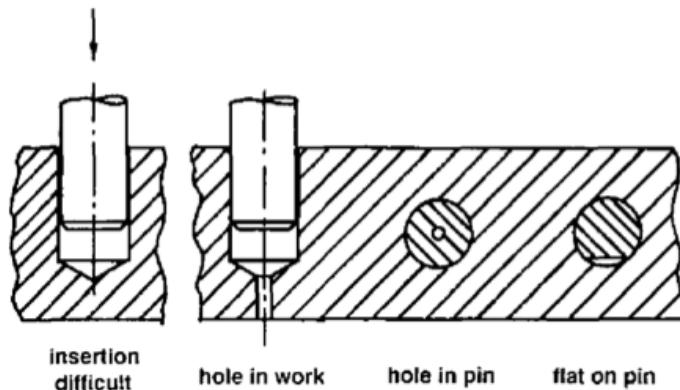
Avoid outside rounds, which are difficult unless CNC-machined.



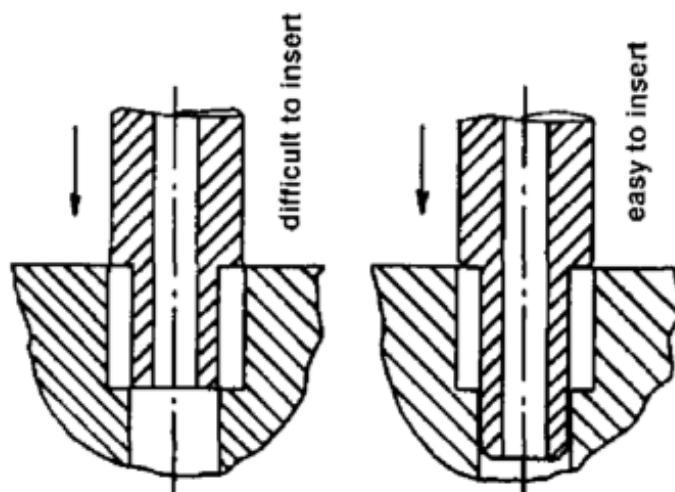
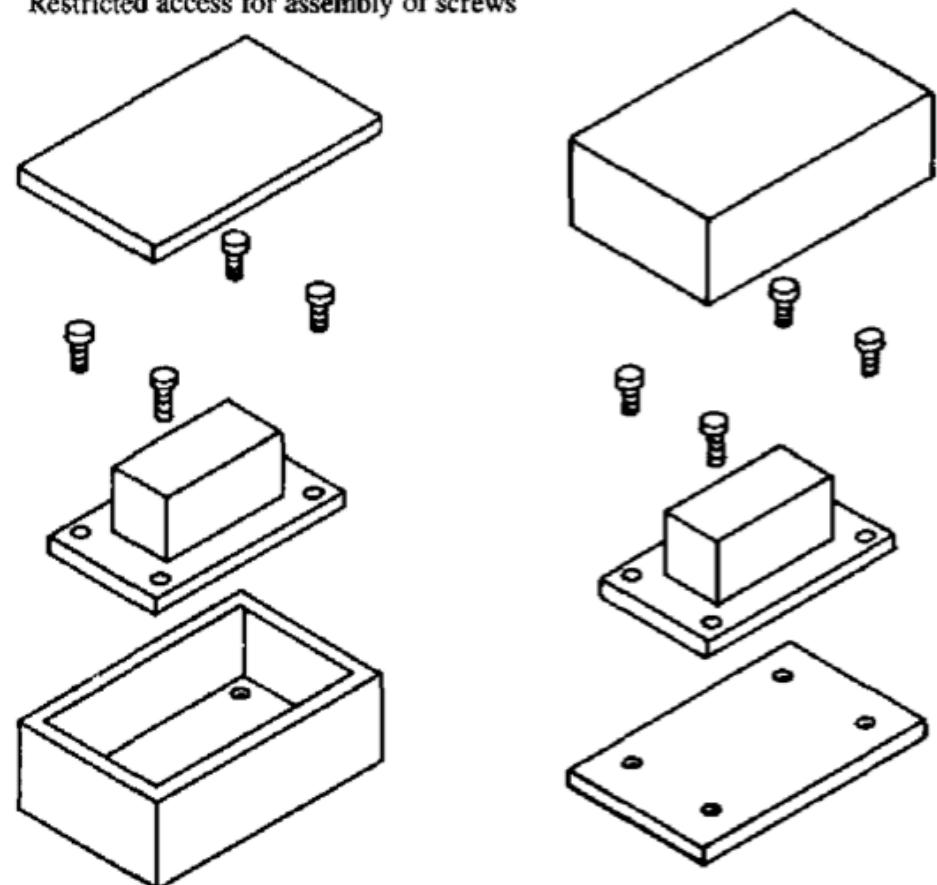
Holes can't change direction.

# DFA (Design for Assembly)

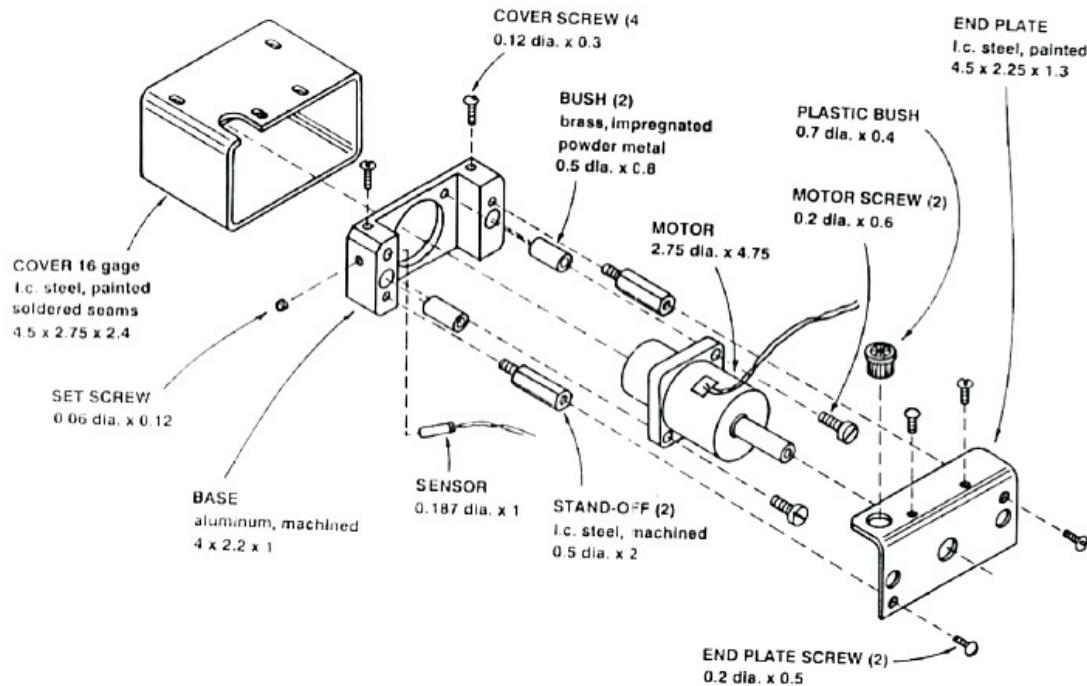
- You should be able to imagine how the parts can be assembled easily, and simplify the assembly procedure.



Restricted access for assembly of screws

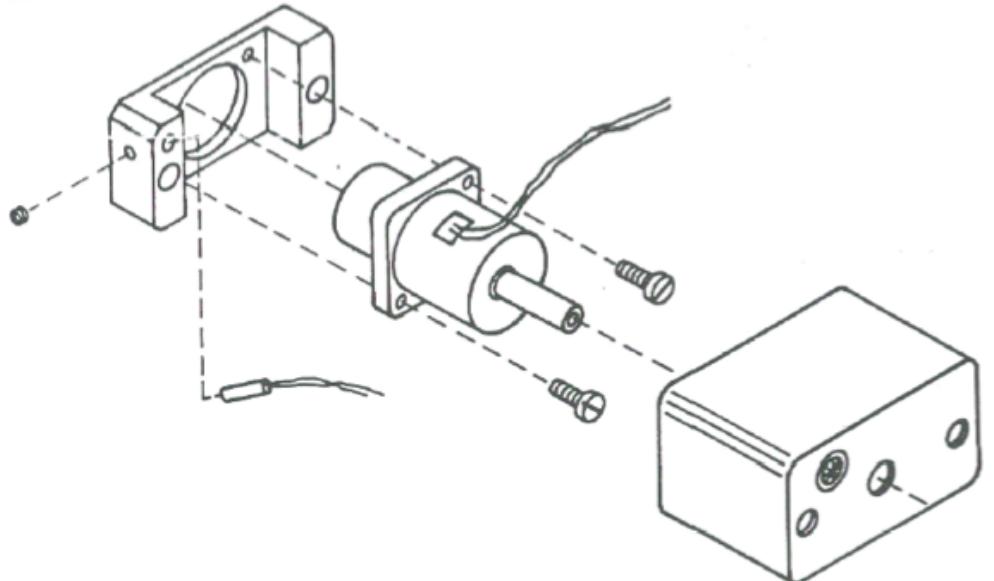


# DFA (Design for Assembly)



*Minimising information content of a product or a process  
(2nd Axiom of Axiomatic Design)*

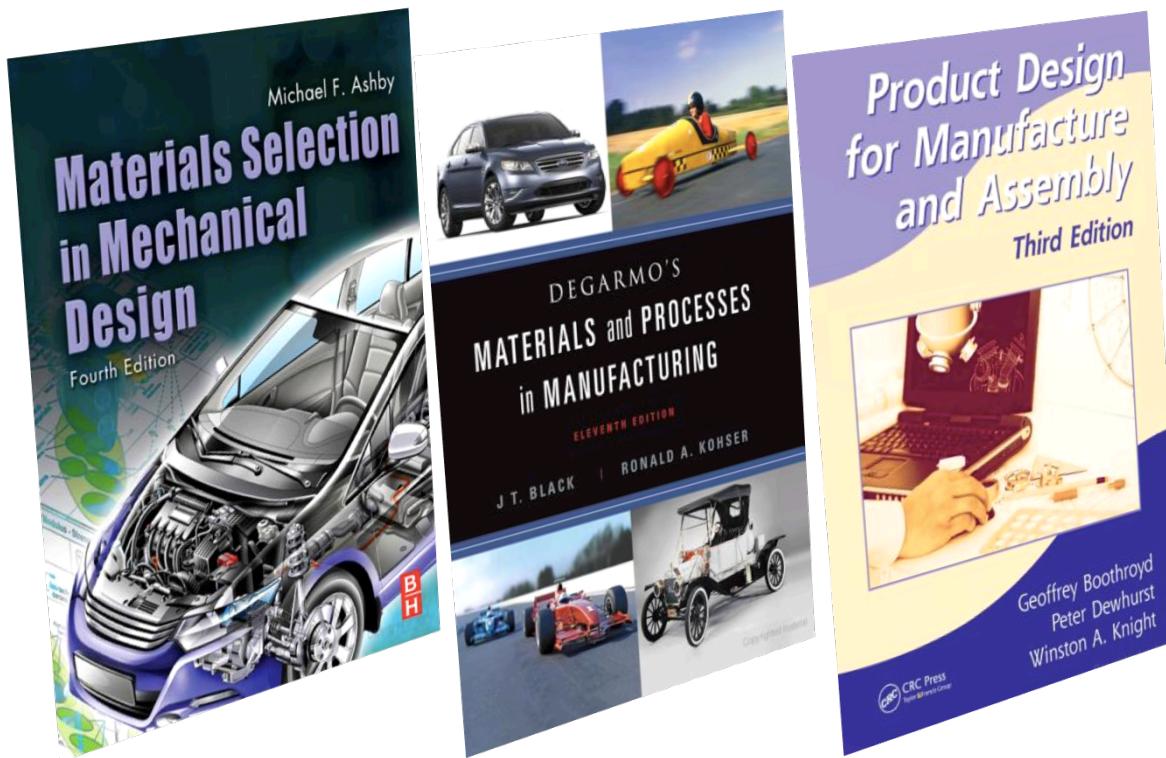
*Your design can hugely affect the speed and cost of the entire production process !!*



# Conclusions

- To become a good engineering designer, you should know about characteristics of engineering materials and their manufacturing processes.
- Through concurrent design (DFM/DFA), you can
  - reduce materials waste
  - save energy
  - increase production speed and reduce cost
  - enhance the efficiency of technicians' works (human resources)
  - reduce the cost for design modification and maintenance
- As students learning engineering design, be interested in how the things around you are being made.

# References



Michael F. Ashby. Materials Selection in Mechanical Design 4th ed., Butterworth-Heinemann, 2011.

E. Paul Degarmo, J T. Black, Ronald A. Kohser. Degarmo's Materials and Processes in Manufacturing 11th ed., John Wiley & Sons, 2011.

Geoffrey Boothroyd, Peter Dewhurst, Winston A. Knight. Product Design for Manufacture and Assembly 3rd ed., CRC Press, 2010.

CES EduPack 2014 is available in computer rooms for students.



# Next Lecture

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**Units of measure and conventions  
by Dr. R. Martine**

**28 November**