Processes: P5 Manufacturing

PRRE1003
Resources, Processes & Materials Engineering

LECTURE P5

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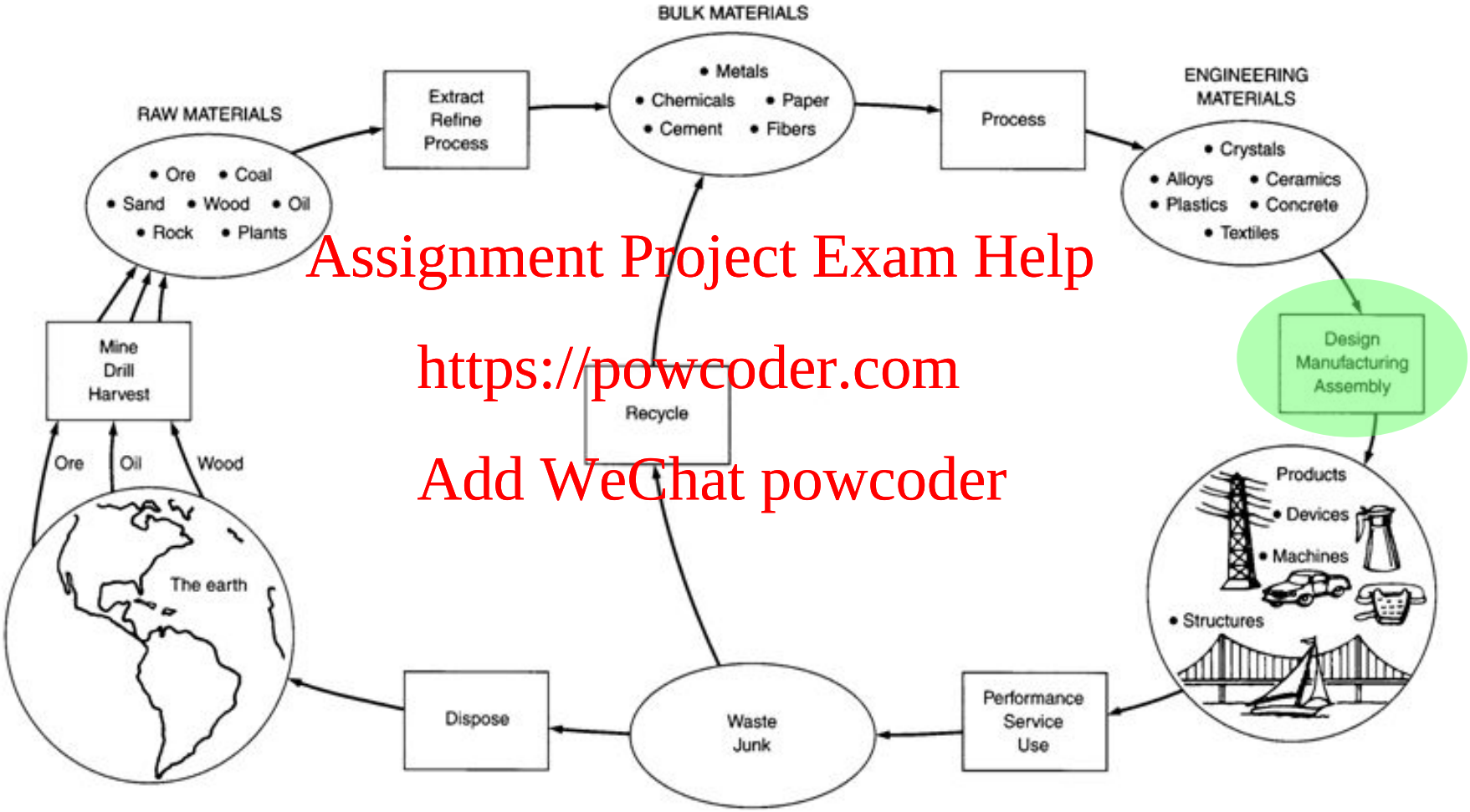
Lecture focus



Reproduced from "Materials and Man's Needs", National Academy of Sciences, Washington D.C., 1974.

Lecture Outline

Materials discovered, extracted and refined …what' next? → Making stuff!!

Focus on Solids → Metals and alloys…then polymers…ceramics …composites

Range of manufacturing processes:

- Primary – Shaping and forming (Bulk)
  - Casting, Forging, Rolling, Extrusion
- Secondary – Fine Forming and Material Removal (Subtractive)

Novel Processes

- Powder metallurgy →… Additive Manufacturing …Lecture 12a

- Polymers
- Ceramics
- Composites

Shaping and Forming of Materials and Components

In order to obtain appropriate engineered products from primary extracted materials a significant number of manufacturing steps need to be undertaken. End users need to obtain products with the right properties, in a suitable finished condition, e.g., for metallic components this is probably in the machined , polished or coated condition.

The component finishing operation is clearly the last stage in the latter stage of manufacture. However, the properties and capabilities of a finished component are heavily influenced by its primary shaping or forming method.

- For example, a cast product is likely to be subject to low fracture toughness whereas a rolled product is likely to be subject to directionality.

These are aspects that need to be understood at the design stage, particularly with respect to performance and economy. Many premature component failures can be avoided if this is done.

Primary Manufacturing Processes

Casting

Casting is a process whereby a material in fluid form is allowed to solidify in a mould to produce a predetermined shape.

As such the method is known as a *shaping* process

Basic requirements for casting

- A process to produce the liquid
- A mould or shape cavity
- A pouring technique
- A solidifying process
- A mould removal process
- A finishing process

Examples of Types of Casting

- Sand Casting
- Die Casting
- Investment Casting

Forming

Starting with a solid form, usually an *ingot* or *billet*.

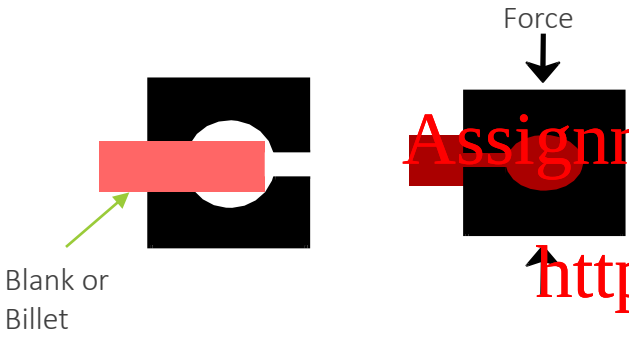
Then using a variety of equipment, forces are applied to the materials, whether hot or cold, to create deformation and therefore shape change and development.

Examples of Forming Processes are:

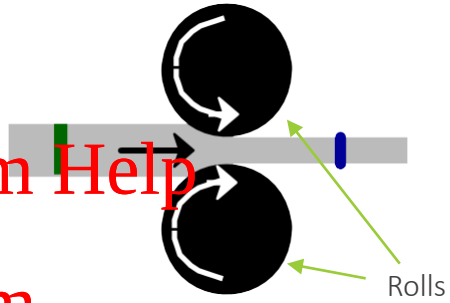
- Forging
- Rolling
- Drawing
- Extrusion

Primary Forming methods for Metals and Alloys

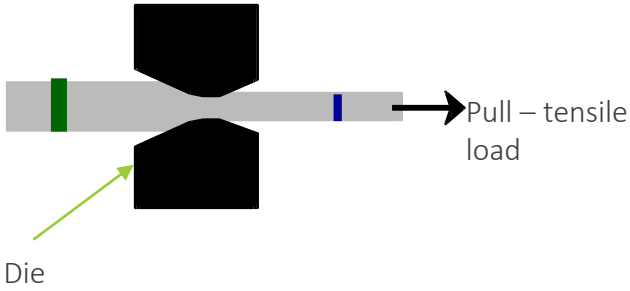
Forging



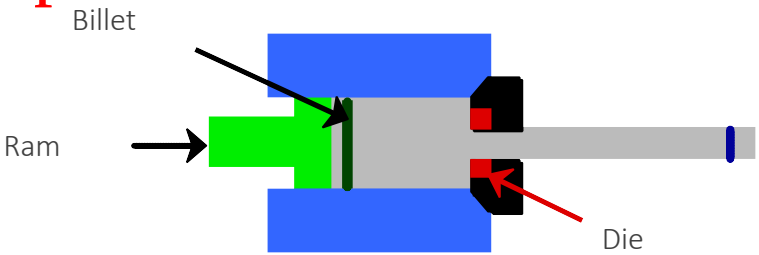
Rolling



Drawing



Extrusion



Learning Outcome Check 1

- What is the difference between a primary and secondary forming process?
- What is the difference between a cast and wrought product?

- What type of material is used for investment casting moulds?

- What type of forces are applied in
  - *forging?*
  - *rolling?*
  - *drawing?*
  - *extrusion?*

Secondary Manufacturing Processes – Metals and Alloys

Cold Forming Methods

Bending
Deep drawing
Stretching
Hollow section (Tube and Pipe) manufacture

Materials Removal Methods (Subtractive)

Machining

- Turning
- Drilling, Boring
- Grinding, Honing, Centreless Grinding (CG)
- Milling
- Computer Numerical Control (CNC)
- Cutting – Shearing, Piercing, Blanking

Joining Methods

Welding

- Oxy acetylene
- Electrode (Stick)
- Metal Inert Gas (MIG)
- Tungsten Inert Gas (TIG)
- Sub – Arc
- Resistance
- Friction

Brazing
Soldering
Fastening

Surface Treatments

Cleaning and Polishing -

- Chemical and Mechanical

Coatings -

- Wet, Dry, Powder, Plating, Hot-Dip, CVD, PVD.

Cladding and Metal Spraying

Powder Metallurgy and Ceramics

Powder Metallurgy

A process by which fine powders of materials are manufactured, shaped and consolidated into finished components. The powders produced by atomisation from the molten form or through comminution.

Process stages

- Mixing or blending (addition of lubricants or binders)
- Compaction – into required shape
- Sintering (not melting!) - ~80% T_m (Hot Isostatic Pressing [HIPing] can combine two stages)
- Optional secondary finishing -
- Finished PM product
- Density?

Ceramics

Due to high melting points and low plasticity of ceramics, manufacturing methods are limited to solid state processes where near-net shape is developed at the outset – hence powder metallurgy procedures including compaction and sintering, or slurry casting/shaping with additives for binding (firing /cementing).

Polymer Component Manufacture

Polymer Types

- Thermosetting
- Thermoplastic
- (Elastomer)

Processes

Many different processes are used depending on the type of polymer

For example,

- Thermosetting Compression - Moulding
- Thermosetting Injection - Moulding
- Extrusion (Section, Pipe, Cable, etc.)
    - Extrusion Blow Moulding
    - Extrusion of Sheet Material
- Blown Film (Plastic Bags)
- Rotational Moulding
- Fibre Production (BCF, Yarn)

Polymer Fabrication Methods

Injection Moulding (most common)

Wide range of components, in terms of size and quantity

Injection Blow Moulding (plastic containers)

Thermoforming

Rotational Moulding

Foam Moulding

A process whereby a foaming agent is mixed with the plastic resin and releases gas or volatilises when the material is heated. The materials expand to between 2 and 50 times their original size.
Example : expanded polystyrene –"Styrofoam"

Glass and Composites

Glass

Glass is generally shaped at elevated temperatures where the viscosity can be controlled, exploiting the property of no discrete Tm.

Sheet and plate can be produced by:

- Extruding through a narrow slit
- Rolling through water cooled rolls
- Floating on to a bath of molten tin

Glass shapes can be produced by pouring directly into a shaped mould Control of cooling rate is critical, to control residual stresses.

Glass fibres can be produced by forcing 'liquid' glass through multiple openings in an extrusion die.

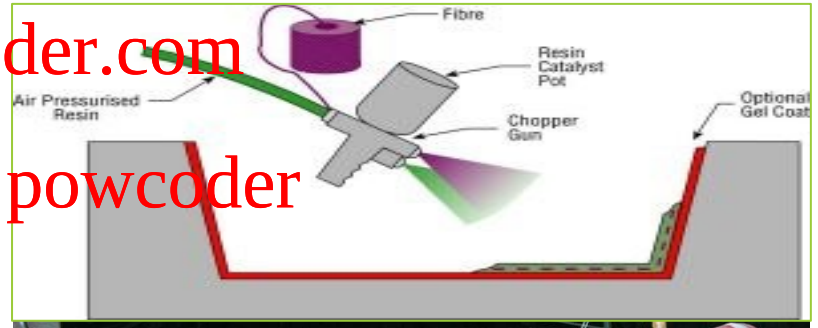
Composites

The geometry, type and material make-up of composite will determine the production method, hence a large degree of variability – can be slow and labour intensive.

Particulate – mixing or blending, e.g., concrete

Laminar – roll bonding, explosive bonding (metals)

Fibre reinforced – filament winding, braiding, weaving, spray moulding,



Glass Fibre Reinforced Polymer (GFRP) composite products

Curtin Motorsport Racing Car Body – produced by spray moulding

Lecture Summary

Everyday we come into contact with hundreds of manufactured items, whether it be at work, at home or at leisure. The materials for these products have originated somehow from the earth's crust.

It is not possible here to cover all of the manufacturing methods applied to primary and secondary products, through to finished goods, though a selection of them has been considered here.

As engineers we need to develop and improve on many of these techniques, and while studying them in detail, we can sometimes take a step back and ask a few simple thought-provoking questions about everyday items…

- Where did the material(s) originate?
- What types of manufacturing processes were applied to create the product?
- What level of energy usage was applied to convert the raw material to its current form?
- How can disposal be undertaken in a sustainable manner?

Learning Outcome Check 2

- For metals and alloys, what is the essential difference between a hot forming process and a cold forming process?
- Why might thermoplastics be more easily shaped?
- What is difference between
  - *welding?*
  - *brazing?*
  - *soldering?*
- In powder metallurgy, what does the sintering process achieve?
- What do you believe is the most widely manufactured composite material?