UNIT I and II

Casting Process
Casting

Refactory mold $\rightarrow$ pour liquid metal $\rightarrow$ solidify, remove $\rightarrow$ finish

- **VERSATILE**: complex geometry, internal cavities, hollow sections
- **VERSATILE**: small ($\sim$10 grams) $\rightarrow$ very large parts ($\sim$1000 Kg)
- **ECONOMICAL**: little wastage (extra metal is re-used)
- **ISOTROPIC**: cast parts have same properties along all directions
• **Casting Process;**
  • Casting is the process of pouring molten metal into the previously made cavity to the desired shape and allow it to solidify.
• **The following are the basic operations of casting process**
  – Pattern making
  – Melting the metal
  – Pouring it into a previously made mould which confirms to the shape of desired component.
• **Pattern**
• A pattern is an element used for making cavities in the mould, into which molten metal is poured to produce a casting.
• **Requirements of a good pattern, and pattern allowances.**
  – Secure the desired shape and size of the casting
  – Simple in design, for ease of manufacture
  – Cheap and readily available
  – Light in mass and convenient to handle
  – Have high strength
• **Pattern materials**
  – Wood
  – Common metals such as Brass, cast Iron, Aluminium and white metal etc.
  – Plastic
  – Gypsum
  – **Pattern allowances**
    – Shrinkage allowance
    – Machining allowance
    – Draft allowance
    – Shake allowance
• Distortion allowance
• Different types of patterns
• Split or Parted Pattern
• Loose Piece Pattern
• Draw backs
• Gated Patterns.
• Match Plate pattern
• Cope and Drag Pattern
• Sweep Patterns.
- MOULD PREPARATION
- Green sand mould:
  - A green sand mould is composed of mixture of sand, clay and water.
- Dry sand mould:
  - Dry sand moulds are basically green sand moulds with 1 to 2% cereal flour and 1 to 2% pitch.
- Materials used in mould preparation
  - Silica sand, Binder, Additives and water
• Various properties of moulding sand.
  • Permeability
  • Strength or Cohesiveness
  • Refractoriness.
  • Plasticity or flowability
  • Collapsibility
  • Adhesiveness.
  • Co-efficient of Expansion
• Different moulding sand test procedures.
• The following tests have been recommended by B.I.S.
• 1. Moisture content test
• 2. Clay content test
• 3. Permeability test
• 4. Fineness test or Sand grain size test (Sieve analysis)
• 5. Strength test
• **CORE MAKING**

• **Core**

  is a body made of refractory material (sand or metal, metal cores being less frequently used), which is set into the prepared mould before closing and pouring it, for forming through holes, recesses, projections, undercuts and internal cavities.

• **Core Prints.** Core prints are the projections on a pattern and are used to make recesses (core seats) in the mould to locate the core
• Casting
• Factors to be considered for selecting a furnace for a job
  • Capacity of molten metal
  • Melting rate and temp armature control desired, Quality of melt required
  • Method of pouring and types of product contemplated.
• **Cupola Furnace operation**

• The cupola is the most widely used furnace in the foundry for melting ferrous and non-ferrous metals and alloys. A cross-section of a cupola is shown. A cupola is a shaft furnace of cylindrical shape erected on legs or columns. The cupola shell is made of steel plate 8 or 10 mm thick. The interior is lined with refractory bricks to protect the shell from getting overheated. The charge for the cupola consists of metallic materials, fuel and fluxes.
## Different Casting Processes

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<tr>
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<td>good finish, low porosity, high production rate</td>
<td>Costly mold, simpler shapes only</td>
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<tr>
<td>Die</td>
<td>Excellent dimensional accuracy, high production rate</td>
<td>costly dies, small parts, non-ferrous metals</td>
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<tr>
<td>Centrifugal</td>
<td>Large cylindrical parts, good quality</td>
<td>Expensive, few shapes</td>
<td>pipes, boilers, flywheels</td>
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Sand Casting
**Sand Casting**

- **cope**: top half
- **drag**: bottom half
- **core**: for internal cavities
- **pattern**: positive

**Diagram:**

- Funnel → sprue → runners → gate → cavity → {risers, vents}
Sand Casting Considerations..

(d) taper
- do we need it?

(e) core prints, chaplets
- hold the core in position
- chaplet is metal (why?)

(f) cut-off, finishing
Shell mold casting

- metal, 2-piece pattern, 175°C-370°C
- coated with a lubricant (silicone)
- mixture of sand, thermoset resin/epoxy
- cure (baking)
- remove patterns, join half-shells → mold
- pour metal
- solidify (cooling)
- break shell → part
Expendable Mold Casting

- Styrofoam pattern
- dipped in refractory slurry $\rightarrow$ dried
- sand (support)
- pour liquid metal
- foam evaporates, metal fills the shell
- cool, solidify
- break shell $\rightarrow$ part
Plaster-mold, Ceramic-mold casting

Plaster-mold slurry: *plaster of paris* (CaSO$_4$), talc, silica flour

Ceramic-mold slurry: silica, powdered Zircon (ZrSiO$_4$)

- The slurry forms a shell over the pattern
- Dried in a low temperature oven
- Remove pattern
- Backed by clay (strength), baked (burn-off volatiles)
- cast the metal
- break mold → part

Plaster-mold:  *good finish* (Why ?)
*plaster: low conductivity* =* low warpage, residual stress
low mp metal* (Zn, Al, Cu, Mg)

Ceramic-mold:  *good finish*
*high mp metals* (steel, …) =* impeller blades, turbines, …
Investment casting (lost wax casting)

(a) Wax pattern (injection molding)

(b) Multiple patterns assembled to wax sprue

(c) Shell built → immerse into ceramic slurry → immerse into fine sand (few layers)

(d) dry ceramic melt out the wax fire ceramic (burn wax)

(e) Pour molten metal (gravity) → cool, solidify [Hollow casting: pouring excess metal before solidification]

(f) Break ceramic shell (vibration or water blasting)

(g) Cut off parts (high-speed friction saw) → finishing (polish)
Die casting

- a type of permanent mold casting
- common uses: components for rice cookers, stoves, fans, washing-, drying machines, fridges, motors, toys, hand-tools, car wheels, …

HOT CHAMBER: (low mp e.g. Zn, Pb; non-alloying)
(i) die is closed, gooseneck cylinder is filled with molten metal
(ii) plunger pushes molten metal through gooseneck into cavity
(iii) metal is held under pressure until it solidifies
(iv) die opens, cores retracted; plunger returns
(v) ejector pins push casting out of ejector die

COLD CHAMBER: (high mp e.g. Cu, Al)
(i) die closed, molten metal is ladled into cylinder
(ii) plunger pushes molten metal into die cavity
(iii) metal is held under high pressure until it solidifies
(iv) die opens, plunger pushes solidified slug from the cylinder
(v) cores retracted
(iv) ejector pins push casting off ejector die
Centrifugal casting

- permanent mold
- rotated about its axis at 300 ~ 3000 rpm
- molten metal is poured

- Surface finish: better along outer diameter than inner,
- Impurities, inclusions, closer to the inner diameter (why ?)
Typical casting defects
UNIT III and IV

WELDING PROCESS
Welding Processes

Fusion Welding Processes

Consumable Electrode

- SMAW – Shielded Metal Arc Welding
- GMAW – Gas Metal Arc Welding
- SAW – Submerged Arc Welding

Non-Consumable Electrode

- GTAW – Gas Tungsten Arc Welding
- PAW – Plasma Arc Welding

High Energy Beam

- Electron Beam Welding
- Laser Beam Welding
Welding

Welding is defined as an localized coalescence of metals, where in coalescence is obtained by heating to suitable temperature, with or without the application of pressure and with or without the use of filler metal.
Different welding processes.

• Fusion Welding, Brazing & Soldering
• Solid State Welding
• Chemical, welding
• Electrical Resistance
• Diffusion, Explosion
• Mechanical
• Cold Friction Ultrasonic
• Oxyfuel gas, hermit welding
• Electron Beam, Laser Beam, Plasma arc welding
Gaswelding.

Gas welding is a group of welding processes where in coalescence is produced by heating with a flame or flames with or without the application of pressure and with or without the use of filler material.
Welding Processes

SMAW – Shielded Metal Arc Welding

- Consumable electrode
- Flux coated rod
- Flux produces protective gas around weld pool
- Slag keeps oxygen off weld bead during cooling

- General purpose welding—widely used
- Thicknesses 1/8” – 3/4”
- Portable

Power... Current I (50 - 300 amps)
Voltage V (15 - 45 volts)

\[ \text{Power} = VI \approx 10 \text{ kW} \]
**SMAW - DC Polarity**

- **Straight Polarity**
  - Shallow penetration
  - (thin metal)
  - AC - Gives pulsing arc
  - used for welding thick sections

- **Reverse Polarity**
  - Deeper weld penetration
GMAW – Gas Metal Arc Welding (MIG)

- DC reverse polarity - hottest arc
- AC - unstable arc

GMAW

- An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool to produce a fusion (melting) together of the base metal.
- The process is used with a shielding gas supplied from an external source without pressure.
GMAW – Gas Metal Arc Welding (MIG)

- **MIG** - Metal Inert Gas
- **Consumable wire electrode**
- **Shielding provided by gas**
- **Double productivity of SMAW**
- **Easily automated**

- DC reverse polarity - hottest arc
- AC - unstable arc

Welding Processes

SAW – Submerged Arc Welding

- 300 – 2000 amps (440 V)

- Consumable wire electrode
- Shielding provided by flux granules
- Low UV radiation & fumes
- Flux acts as thermal insulator
- Automated process (limited to flats)
- High speed & quality (4 – 10x SMAW)
- Suitable for thick plates

http://www.twi.co.uk
GTAW – Gas Tungsten Arc Welding (TIG)

- a.k.a. TIG - Tungsten Inert Gas
- Non-consumable electrode
- With or without filler metal
- Shield gas usually argon
- Used for thin sections of Al, Mg, Ti.
- Most expensive, highest quality

Current I

- (200 A DC)
- (500 A AC)

Power \( \approx 8-20 \text{ kW} \)
Friction Welding (Inertia Welding)

- One part rotated, one stationary
- Stationary part forced against rotating part
- Friction converts kinetic energy to thermal energy
- Metal at interface melts and is joined
- When sufficiently hot, rotation is stopped & axial force increased
Resistance Welding is the coordinated application of electric current and mechanical pressure in the proper magnitudes and for a precise period of time to create a coalescent bond between two base metals.

- Heat provided by resistance to electrical current ($Q=I^2Rt$)
- Typical 0.5 – 10 V but up to 100,000 amps!
- Force applied by pneumatic cylinder
- Often fully or partially automated
  - Spot welding
  - Seam welding
Resistance Welding

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- Force applied by pneumatic cylinder
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- Often fully or partially automated
  - Spot welding
  - Seam welding
• Parts forced together at high temperature (< 0.5Tm absolute) and pressure
• Heated in furnace or by resistance heating
• Atoms diffuse across interface
• After sufficient time the interface disappears
• Good for dissimilar metals
• Bond can be weakened by surface impurities

Soldering & Brazing

• Only filler metal is melted, not base metal

• Lower temperatures than welding

• Filler metal distributed by capillary action

• Metallurgical bond formed between filler & base metals

• Strength of joint typically
  – stronger than filler metal itself
  – weaker than base metal
  – gap at joint important (0.001 – 0.010”)

• Pros & Cons
  – Can join dissimilar metals
  – Less heat - can join thinner sections (relative to welding)
  – Excessive heat during service can weaken joint
LASER BEAM WELDING
Laser Beam Welding (LBW)

Keyhole welding

Laser beam
Plasma plume
Molten material
workpiece motion

Keyhole welding
Focusing the Beam

Heat treatment
Surface modification
Welding
Cutting

High Energy Density Processes
Advantages

- Single pass weld penetration up to 3/4” in steel
- High Travel speed
- Materials need not be conductive
- No filler metal required
- Low heat input produces low distortion
- Does not require a vacuum
**Soldering**

**Solder** = Filler metal
- Alloys of Tin (silver, bismuth, lead)
- Melt point typically below 840 °F

**Flux** used to clean joint & prevent oxidation
- separate or in core of wire (rosin-core)

**Tinning** = pre-coating with thin layer of solder

Applications:
- Printed Circuit Board (PCB) manufacture
- Pipe joining (copper pipe)
- Jewelry manufacture
- Typically non-load bearing

Easy to solder: copper, silver, gold
Difficult to solder: aluminum, stainless steels
(can pre-plate difficult to solder metals to aid process)
Manual PCB Soldering

• Soldering Iron & Solder Wire

• Heating lead & placing solder

• Heat for 2-3 sec. & place wire opposite iron

• Trim excess lead
Automated Reflow Soldering

- Solder/Flux paste mixture applied to PCB using screen print or similar transfer method

- Solder Paste serves the following functions:
  - supply solder material to the soldering spot,
  - hold the components in place prior to soldering,
  - clean the solder lands and component leads
  - prevent further oxidation of the solder lands.

- PCB assembly then heated in “Reflow” oven to melt solder and secure connection

SMT = Surface Mount Technology

Printed solder paste on a printed circuit board (PCB)
Brazing

Use of low melt point filler metal to fill thin gap between mating surfaces to be joined utilizing capillary action

- Filler metals include Al, Mg & Cu alloys (melt point typically above 840 F)
- Flux also used
- Types of brazing classified by heating method:
  - Torch, Furnace, Resistance

Applications:
- Automotive - joining tubes
- Pipe/Tubing joining (HVAC)
- Electrical equipment - joining wires
- Jewelry Making
- Joint can possess significant strength
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Welding defects

- **Misalignment** (hi-lo)
- **Undercut**
- **Underfill**
- **Concavity or Convexity**
- **Excessive reinforcement**
- **Improper reinforcement**
- **Overlap**
- **Burn-through**
- **Incomplete or Insufficient Penetration**
- **Incomplete Fusion**
- **Surface irregularity**
  - Overlap
- **Arc Strikes**
- **Inclusions**
  - Slag
  - Wagontracks
  - Tungsten
- **Spatter**
- **Arc Craters**
- **Cracks**
  - Longitudinal
  - Transverse
  - Crater
  - Throat
  - Toe
  - Root
  - Underbead and Heat-affected zone
  - Hot
  - Cold or delayed
- **Base Metal Discontinuities**
  - Lamellar tearing
  - Laminations and Delaminations
  - Laps and Seams
- **Porosity**
  - Uniformly Scattered
  - Cluster
  - Linear
  - Piping
- **Heat-affected zone microstructure alteration**
- **Base Plate laminations**
- **Size or dimensions**
UNIT V AND VI
Forming process

• **Hot working:**
  The Metal working process which is done above recrystallisation temperature is known as hot working.

• **Cold working:**
  The metal working process which is done below recrystallisation temperature is known as cold working.
• **Hot working:**
  The Metal working process which is done above recrystallisation temperature is known as **hot working**.

• **Cold working:**
  The metal working process which is done below recrystallisation temperature is known as **cold working**.
• **Recrystallisation temperature.**

  When a metal is heated and deformed under mechanical force, an energy level will be reached when the old grain structure starts disintegrating, and entirely new grain structure (equip axed, stress free) with reduced grain size starts forming simultaneously. This phenomenon is known as recrystallisation, and the temperature at which this phenomenon starts called recrystallisation temperature.
• **Advantages of hot working:-**
  • Very large work pieces can be deformed with equipment of reasonable size.
  • Strength of the metal is low at high temperature. Hence low tonnage equipments are adequate for hot working.
  • Grain size can be controlled to be minimum.

• **Advantages of cold working:-**
  • Surface defects are removed.
  • High dimensional accuracy.
  • Cold working is done at room temperature, no oxidation and scaling of the work material occurs.
Drawing.

- **Drawing** is a cold working process in which the work piece is pulled through a tapered hole in a die so as to reduce its diameter. The process imparts accurate dimensions, specified cross – section and a clean excellent Quality of surface to the work.

- **Degree of drawing (RA).**

- The degree of drawing is measured in terms of “reduction of area” which is defined as the ratio of the difference in cross – sectional area before and after drawing to the initial cross sectional area expressed in percent.
Drawing

Similar to extrusion, except: *pulling force* is applied

Commonly used to make wires from round bars
• **DRAWING**

• Drawing is a cold working process in which the work piece (wire, rod or tube) is pulled through a tapered hole in a die so as to reduce its diameter. The process imparts accurate dimensions, specified cross section and a clean and excellent quality of surface to the work. The process may appreciably increase the strength and hardness of metal.
Rolling.

- Rolling is the process in which the metals and alloys are plastically deformed into semi-finished or finished condition by passing these between circular rolls. The main objective in rolling is to decrease the thickness of metal.

- The faster method is to pass the stock through a series of rolls for successive reduction, but this method requires more investment in equipment.
• Tube drawing
• Tubes which are made by hot metal working, processes are finally cold drawn to obtain better surface finish and dimensional tolerances, to enhance the mechanical properties of the pipe, and to produce tubes of reduced wall thickness.
(a) A Typical Drawing Die

(b) Wire Drawing

(c) Rod Drawing
Types of rolling mills

- Two high rolling mill
- Three high rolling mill
- Four-high rolling mill
- Multiple –roll mills
Fig. Rolling Mills.
Forging.

• Forging may be defined as a metal working process by which metals and alloys are plastically deformed to desired shapes by the application of compressive force. Forging may be done either hot or cold.
Forging

[Heated] metal is beaten with a heavy hammer to give it the required shape.
Stages in Closed-Die Forging

1. Blank (bar)
2. Edging
3. Blocking
4. Finishing
5. Trimming

[source: Kalpakjian & Schmid]
Stages in Open-Die Forging

(a) forge hot billet to max diameter

(b) “fuller: tool to mark step-locations

(c) forge right side

(d) reverse part, forge left side

(e) finish (dimension control)

[source:www.scotforge.com]
• Basic Forging Operations
  • . Upsetting
  •  Heading
  •  Fullering
  • . Drawing down
  •  Edging
  • . Bending
  •  Flattening
  • . Blocking
  •  Cut – off
  •  Piercing
  •  Punching
Quality of forged parts

Surface finish/Dimensional control:
Better than casting (typically)

Stronger/tougher than cast/machined parts of same material

[source:www.scotforge.com]
(d) EDGING

(e) DRAWING DOWN
Extrusion.

- Extrusion may be defined as the manufacturing process in which a block of metal enclosed in a container is forced to flow through the opening of a die. The metal is subjected to plastic deformation and it undergoes reduction and elongation during extrusion.
Extrusion

Metal forced/squeezed out through a hole (die)

Typical use: ductile metals (Cu, Steel, Al, Mg), Plastics, Rubbers

Common products:

Al frames of white-boards, doors, windows, …
• **Direct Extrusion:**
  eated billet is placed in the container. It is pushed by ram towards the die. The metal is subjected to plastic deformation, slides along the wall of the container and is forced to flow through die opening.
  Ram movement = Extruded material movement.

• **Indirect Extrusion:**
  In this type of extrusion, the extruded material movement is opposite to that of ram movement. In indirect extrusion there is practically no slip of billet with respect to container walls.
FORGING HAMMERS

• **Pneumatic forging hammer**
• Hydraulic presses Direct – drive hydraulic presses
• Accumulator – driven hydraulic presses
Sheet Metal Processes

Raw material: sheets of metal, rectangular, large

Raw material Processing: Rolling (anisotropic properties)

Processes:
- Shearing
- Punching
- Bending
- Deep drawing
Shearing

A large scissors action, cutting the sheet along a straight line

Main use: to cut large sheet into smaller sizes for making parts.
Punching

Cutting tool is a round/rectangular punch, that goes through a hole, or die of same shape.

\[ F \propto t \times \text{edge-length of punch} \times \text{shear strength} \]

- Punch
- Die
- Sheet
- Crack (failure in shear)
- Piece cut away, or slug
- Clearance
Punching

Main uses: cutting holes in sheets; cutting sheet to required shape

Exercise: how to determine optimal nesting?
Bending

Body of Olympus E-300 camera

component with multiple bending operations

component with punching, bending, drawing operations

[Image source: dpreview.com]
Typical bending operations and shapes

(a) Channel forming  (b) Joggle  (c) Hemming (flattening)  (d) Two-stage lock seam  (e) Offset forming

(b) Straight flange  Stretch flange  Shrink flange  Joggled flange  Reverse flange
Sheet metal bending

Planning problem: what is the sequence in which we do the bending operations?

Avoid: part-tool, part-part, part-machine interference
Bending mechanics

Bending Planning ➔ what is the length of blank we must use?

Bend allowance, \( L_b = \alpha (R + kT) \)

This section is under extension

Neutral axis

This section is in compression

\( T = \text{Sheet thickness} \)

\( L = \text{Bend length} \)

\( R = \text{Bend radius} \)

Ideal case: \( k = 0.5 \)

Real cases: \( k = 0.33 \ (R < 2T) \sim k = 0.5 \ (R > 2T) \)
Bending: cracking, anisotropic effects, Poisson effect

Bending $\Rightarrow$ plastic deformation

Engineering strain in bending $= e = \frac{1}{(1 + 2R/T)}$

Bending $\Rightarrow$ disallow failure (cracking) $\Rightarrow$ limits on corner radius: bend radius $\geq 3T$

Effect of anisotropic stock

Poisson effect

Exercise: how does anisotropic behavior affect planning?
Bending: springback

How to handle springback:

(a) Compensation: the metal is bent by a larger angle

\[ \frac{R_i}{R_f} = 4 \left( \frac{R_i Y}{ET} \right)^3 - 3 \left( \frac{R_i Y}{ET} \right) + 1 \]

(b) Coining the bend:

at end of bend cycle, tool exerts large force, dwells

coining: press down hard, wait, release
Deep Drawing

Tooling: similar to punching operation,
Mechanics: similar to bending operation

(a) (b) (c) (d) (e) Examples of deep drawn parts

Common applications: cooking pots, containers, …
Sheet metal parts with combination of operations

Body of Olympus E-300 camera

component with multiple bending operations

component with punching, bending, drawing operations
Powder Metallurgy
Example Parts
Basic Steps In Powder Metallurgy (P/M)

• Powder Production
• Blending or Mixing
• Compaction
• Sintering
• Finishing
Powder Production

- Atomization the most common
- Others
  - Chemical reduction of oxides
  - Electrolytic deposition
- Different shapes produced
  - Will affect compaction process significantly
Blending or Mixing

• Can use master alloys, (most commonly) or elemental powders that are used to build up the alloys
  – Master alloys are with the normal alloy ingredients
• Elemental or pre-alloyed metal powders are first mixed with lubricants or other alloy additions to produce a homogeneous mixture of ingredients
• The initial mixing may be done by either the metal powder producer or the P/M parts manufacturer
• When the particles are blended:
  – Desire to produce a homogenous blend
  – Over-mixing will work-harden the particles and produce variability in the sintering process
Compaction

- Usually gravity filled cavity at room temperature
- Pressed at 60-100 ksi
- Produces a “Green” compact
  - Size and shape of finished part (almost)
  - Not as strong as finished part – handling concern
- Friction between particles is a major factor
Isostatic Pressing

- Because of friction between particles
  - Apply pressure uniformly from all directions (in theory)
- Wet bag (left)
- Dry bag (right)
Sintering

- Parts are heated to \(~80\%\) of melting temperature
- Transforms compacted mechanical bonds to much stronger metal bonds
- Many parts are done at this stage. Some will require additional processing
Sintering ctd

- Final part properties drastically affected
- Fully sintered is not always the goal
  - Ie. Self lubricated bushings
- Dimensions of part are affected

![Graph showing changes in density, strength, and ductility over time.](image)

![Diagram showing steps from green compact to fully sintered.](image)
Die Design for P/M

- Thin walls and projections create fragile tooling.
- Holes in pressing direction can be round, square, D-shaped, keyed, splined or any straight-through shape.
- Draft is generally not required.
- Generous radii and fillets are desirable to extend tool life.
- Chamfers, rather the radii, are necessary on part edges to prevent burring.
- Flats are necessary on chamfers to eliminate feather-edges on tools, which break easily.
Advantages of P/M

- Virtually unlimited choice of alloys, composites, and associated properties
  - Refractory materials are popular by this process
- Controlled porosity for self lubrication or filtration uses
- Can be very economical at large run sizes (100,000 parts)
- Long term reliability through close control of dimensions and physical properties
- Wide latitude of shape and design
- Very good material utilization
Disadvantages of P/M

- Limited in size capability due to large forces
- Specialty machines
- Need to control the environment – corrosion concern
- Will not typically produce part as strong as wrought product. (Can repress items to overcome that)
- Cost of die – typical to that of forging, except that design can be more – specialty
- Less well known process
Financial Considerations

• Die design – must withstand 100 ksi, requiring specialty designs

• Can be very automated
  – 1500 parts per hour not uncommon for average size part
  – 60,000 parts per hour achievable for small, low complexity parts in a rolling press

• Typical size part for automation is 1” cube
  – Larger parts may require special machines (larger surface area, same pressure equals larger forces involved)
Extrusion

- Raw materials in the form if thermoplastic pallets, granules, or powder, placed into a hopper and fed into extruder barrel.

- The barrel is equipped with a screw that blends the pallets and conveys them down the barrel.

- Heaters around the extruder’s barrels heats the pellets and liquefies them.

Screw has 3-sections
- Feed section
- Melt or transition section
- Pumping section.
• Complex shapes with constant cross-section

• Solid rods, channels, tubing, pipe, window frames, architectural components can be extruded due to continuous supply and flow.

• Plastic coated electrical wire, cable, and strips are also extruded

Pellets : extruded product is a small-diameter rod which is chopped into small pellets

Sheet and film extrusion :
Extruded parts are rolled on water and on the rollers
Fig: Schematic illustration of a typical extruder for plastics, elastomers, and composite materials.
**Injection molding**

Fig: Injection molding with (a) plunger, (b) reciprocating rotating screw, (c) a typical part made from an injection molding machine cavity, showing a number of parts made from one shot, note also mold features such as sprues, runners and gates.
• Similar to extrusion barrel is heated

• Pellets or granules fed into heated cylinder

• Melt is forced into a split-die chamber

• Molten plastic pushed into mold cavity

• Pressure ranges from 70 Mpa – 200 Mpa

• Typical products : Cups, containers, housings, tool handles, knobs, electrical and communication components, toys etc.
Injection molding

- Injection molds have several components such as runners, cores, cavities, cooling channels, inserts, knock out pins and ejectors.

3-basic types of molds
- Cold runner two plate mold
- Cold runner three plate mold
- Hot runner mold

Fig: Examples of injection molding
Injection Molding Machine

Fig: A 2.2-MN (250-ton) injection molding machine. The tonnage is the force applied to keep the dies closed during injection of molten plastic into the mold cavities.
Process capabilities:

- High production rates
- Good dimensional control
- Cycle time range 5 to 60 sec’s
- Mold materials - tool steels, beryllium - Cu, Al
- Mold life - 2 million cycles (steel molds)
  10000 cycles (Al molds)

Machines:
- Horizontal or vertical machines
- Clamping – hydraulic or electric
**Blow molding**

- Modified extrusion and Injection Molding process.
- A tube extruded then clamped to mold with cavity larger than tube diameter.
- Finally blown outward to fill the cavity
- Pressure 350Kpa-700Kpa

Other Blow Molding processes
- Injection Blow molding
- Multi layer Blow molding
Fig: Schematic illustration of (a) the blow-molding process for making plastic beverage bottles, and (b) a three-station injection blow-molding machine.
Rotational Molding

- Thermo plastics are thermosets can be formed into large parts by rotational molding
- A thin walled metal mold is made of 2 pieces
- Rotated about two perpendicular axes
- Pre-measured quantity of powdered plastic material is rotated about 2-axes
- Typical parts produced-Trash cans, boat hulls, buckets, housings, toys, carrying cases and foot balls.
Fig: The rotational molding (rotomolding or rotocasting) process. Trash cans, buckets, and plastic footballs can be made by this process.
Thermoforming

- Series process for forming thermoplastic sheet or film over a mold by applying heat and pressure.
- Typical parts: advertising signs, refrigerator liner, packaging, appliance housing, and panels for shower stalls.

Fig: Various Thermoforming processes for thermoplastic sheet. These processes are commonly used in making advertising signs, cookie and candy trays, panels for shower stalls, and packaging.
Compression molding

- Pre-shaped charge, pre-measured volume of powder and viscous mixture of liquid resin and filler material is placed directly into a heated mold cavity.

- Compression mold results in a flash formation which is an excess material.

- Typical parts made are dishes, handles, container caps fittings, electrical and electronic components and housings

- Materials used in compression molding are thermosetting plastics & elastomers

- Curing times range from 0.5 to 5 mins

3- Types of compression molds are

- Flash type
- Positive type
- Semi-positive
Compression Molding

Fig: Types of compression molding, a process similar to forging; (a) positive, (b) semi positive, (c) flash (d) Die design for making compression-molded part with undercuts.
Transfer molding

• Transfer molding is an improvement if compression molding

• Uncured thermosetting material placed in a heated transfer pot or chamber, which is injected into heated closed molds

• Ram plunger or rotating screw feeder forces material into mold cavity through narrow channels

• This flow generates heat and resin is molten as it enters the mold

Typical parts: Electrical & electronic components, rubber and silicone parts
Transfer molding

Fig: Sequence of operations in transfer molding for thermosetting plastics. This process is particularly suitable for intricate parts with varying wall thickness.
Casting

Conventional casting of thermo plastics :

- Mixture of monomer, catalyst and various additives are heated and poured into the mould
- The desired part is formed after polymerization takes place.

Centrifugal casting :

- Centrifugal force used to stack the material onto the mold
- Reinforced plastics with short fibers are used

Fig : Casting
Cold forming
- Processes such as rolling, deep drawing, extrusion, closed die forging, coining, and rubber forming can be used for thermoplastics at room temperatures.
- Typical materials used: Polypropylene, poly carbonate, Abs, and rigid PVC.

Considerations:
- Sufficiently ductile material at room temperature.
- Non recoverable material deformation.

Solid Phase forming
- Temperatures from 10°C to 20°C are maintained, which is below melting point.

Advantages:
- Spring-back is lower.
- Dimensional accuracy can be maintained.
Calendaring and Examples of Reinforced Plastics

Fig: Reinforced-plastic components for a Honda motorcycle. The parts shown are front and rear forks, a rear swing arm, a wheel, and brake disks.

Fig: Schematic illustration of calendaring, Sheets produced by this process are subsequently used in thermoforming.
Fig: The manufacturing process for producing reinforced-plastic sheets. The sheet is still viscous at this stage; it can later be shaped into various products.
Examples of Molding processes

Fig: (a) Vacuum-bag forming. (b) Pressure-bag forming.

Fig: Manual methods of processing reinforced plastics: (a) hand lay-up and (b) spray-up. These methods are also called open-mold processing.
THE END