ME 206 Manufacturing Processes I (S1)

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1 Introduction

- The five M's of the manufacturing define the profitability of the manufacturing process
  - Men (women)
  - Machine
  - Materials
  - Money
  - Management
- Manufacturing processes can be classified into:
  - Shaping processes
  - alter the shape
    * Solidification process
    * Metal Removal process
    * Deformation process
    * Assembly process
  - Property enhancing processes
  - change the properties of the material
    Ex: annealing, hardening
  - Surface enhancing processes
  - clean the surfaces or coat them
    Ex: Surface oxidation
- Selection of manufacturing processes depends on various factors
  - Cost
  - Available infrastructure
  - Operating temperature
  - Required properties
  - Dimensions of required product

2 Casting Process

Pros:

- Complex forms, low cost
- Certain shapes cannot be machined
- One piece parts vs. multiple piece parts
- Design changes are easily incorporated
- High volume, low skilled labor
- Large, heavy parts can be made easily

Cons:

- Problems with internal porosity
- Dimensional variations due to shrinkage
- Trapped impurities, solids and gasses
- High-tolerance, smooth surfaces not possible
- More costly than stamping or extruding in some cases

2.1 Pattern

- It is the replica (usually a bit bigger) of the req product
- It should be cost efficient, easily machinable into common shapes.
  Possible choices are:
  - Wood : more than 90% of the production happens with wood, absorbs moisture, relatively lower life
  - Metal: longer life, used in large quantity production, Al, cast iron and bronze are most used
  - Plastic : good corrosion resistance, smooth surfaces, do not absorb moisture, dimensionally stable, low weight
- Pattern types
  - Single piece pattern: Name says it all
  - Split pattern
  - Cope
  - split pattern: Same as split pattern except that parts are moulded seperately
  - Gated pattern: Tree like structure with each branch holding the required shape

2.2 Allowances

- Draft/ Taper Allowance
  To avoid damage to the sand mould on the internal walls, we need to provide extra material on the walls of the pattern. We typically use a tapering angle(angle at which pattern is bent outwards).
- Machining/Finishing allowance
  It is the extra material allowed to cut to smooth finish the product. The amount of machining depends on method of moulding method of molding and casting used, size and shape of casting, metal used in casting, required accuracy and finish
- Distortion / Camber allowance
  Due to typical shape of some patterns (non symmetric) (T, U, V, W), after cooling down the shape will change due to uneven shrinkage, so we need to allow distortion allowance i.e, we need to bend the pattern in opp dir to the expected distortion to get correct shape. This varies between 2 to 20 mm.

2.3 Molds

- Expendable Molds: A new mold has to be produced for every cycle. Types: green sand, dry sand, shell, investment, plaster
- Permanent molds: Multiple usages, used in: die casting, centrifugal, pressure die, injection molding
- Required properties of moulding sand:
  - Refractoriness: Ability to withstand higher temperatures
  - Permeability: For the air to escape
  - Cohesiveness: Adhesive forces in sand
  - Flowability: It should flow uniformly to all the portions
- A top gating design is prefered over bottom gating design and parting gating design because in the case of top gating design, the gravity help the molten metal to flow to intricate corners of the pattern.

2.4 Types of Casting

- Sand casting:
  Advantages - This is cheap, this can be used ferrous and non-ferrous materials. (Non ferrorus metals require high temp)
  Disadvantages - Rough finish
- Investment casting

  - We first create a pattern out of wax(optimisied for this process) and then dip it in slurry (silica). The slurry solidify on the outer surface to req thickness. Then we heat the thing to melt wax and remove the wax completely to create a outer wall for the req shape. The liq metal is poured into the solid slurry to create the req shape. After cooling down, outer shell can be removed
  - This has a smooth wall finish
  - It can be used to create complex shapes because wax can be easily bended
  - Also known as lost wax casting precision casting
  - This is relatively expensive compared to sand casting

- Centrifugal casting
  - Molten metal is poured into a long cylinder and rotated, and it is cooled on the outer surface
  - The outer part cools faster and have smaller grain size
  - The lighter impurities present in the metal get accumulated at the inner surface. This can be removed by machining process in the inner surface

- Shell moulding
  - The req shape in metal in heated and some silica or sand made to stick to the metal and a outer shell is made.
  - Then liquid metal is poured into the mould.
  - Axial symmetry things can be made easily by this.

- Lost Foam/ Evaporation Pattern
  - A pattern is created is using polystryene and sand is used to support it.
  - The metal is directly poured into the polystryene and the polymer evaporates and creating req shape

- Continuous casting
  - Partially solidified (outer surface) metal is sent through the roller and cooling liquid is sprayed
  - This creates uninterupted long strands of metal

- (Pressure) Die casting
  - High cost
  - The dies are two shapes which lock into each creating a cavity in between.
  - Before locking they are sprayed with some liq to prevent sticking of molten metal to die
  - Metal is poured is cavity and pressure is applied to molten metal. Pressure ensures that metals reaches all the cavities and ensures that metal reaches everywhere before it start solifidies. After removing ejector pins, dice get seperated.
  - Cooling channels are present in the die which cool the metal. The whole can be completed as fast as 1min.
  - In cold chamber die casting - higher melting point metals (prefered because it can cost higher to maintain metal in liq state)
  - In hot cold chamber die casting - lower melting metal (can also be used for higher melting metal)

2.5 Casting Defects

(todo : more on this)

- Misrun : metal solidified before reaching all places
- cold shut : meeting of two metal streams
- cold shot : resulted due to turbulence during casting process
- Sand blow : The gas bubble in the cavity which entered the during pouring stays in the cavity and create bubble shaped cavity.
- Pinholes : The small pours in the metal which are due to the gases which are released during solidification

2.6 Trends

(todo : more on this)

- Change in casting metal
  - Steel to ductile iron - lower material and conversion cost
  - Al to Al-Mg-Ti alloys - increase in stength to weight ratio
  - In alloy casting, we need to ensure that the composition remains the same throughout.
- Change in geometry
  - Wall thickness is reducing. This is because in casting of thick pieces, distortion happens and we want straight parts. In case, we have multiple thickness, then we can use chill to start solidification earlier at thicker points
  - Weight reduction and increasing shape complexity

3 Metal flow in typical casting

- Metal flow is turbulent
- When metal flows against the mold wall, erosion occurs, vortex formation, splashing against the mold walls, air aspiration(due to reaction with mold material) and metal solidification.
- We can determine the reynold's numbers of molten metal flowing and determine the reynolds' number
- Velocity of the metal gets reduced due to loss by sudden change in cross section, etc.

$$v_{actual} = c_d\sqrt{2gh}$$

- Typical value of C_d is 0.6-0.8
- Friction can be ignored for considering loss in velocity of metal, losses due to change in cross section dominate the losses
- For multiple top gates, L gate has high c_d compared to T gate. L gate has the highest flow rate (even if it is the farthest) due to inertia.
- To reduce defects in casting process due to erosion of sand mould, we need to ensure that stress due to impact ¿ sand mould strength
- velocity of the metal should not be very high, because high vel makes erosion and causes defects in metal product
- Turbulence causes mixing with air, sand erosion
- Desired $Re < 8000$

$$Re = \frac{\rho v D}{\mu}$$

- Surface turbulence - Weber number

$$W_e = \frac{\rho v^2 d}{\gamma}$$

  $W_e < 1$: No surface turbulence
  $W_e < 10$: Mild
  $W_e < 100$: High turbulence

- Bond number (Related to buoyancy)

$$B = \frac{\rho d^2 g}{\gamma}$$

  $B < 1$: Surface tension dominate
  $B > 1$: Buoyancy dominates surface tension

- **Fluidity** in case of metal casting refers to the distance the metal can travel before solidifying. This is different from the physics defination(inverse of viscosity)
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