

# **Review of Manufacturing Processes**

ME 682

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# Engineering Materials

- The four major categories:
  - Metal
  - Plastics
  - Ceramics
  - Composites
- **1- Metals:**
  - Cast: ferrous and non-ferrous
  - Wrought: ferrous and non-ferrous
  - Properties for selection: strength (tensile, yield, shear), modulus, elongation, hardness, endurance limit, density, thermal conductivity, coefficient of thermal expansion, and electrical conductivity. See tables A9.1 and A9.2 in textbook.

# Engineering Materials (Ctd)

- **2- Plastics:**
  - Thermoplastics
  - Thermoset materials
- **Thermoplastics:**
  - Crystalline (narrow melting range, opaque, good fatigue and wear resistance, high shrinkage, high melt temperature and melt viscosities). Examples: nylon, polyethylene, acetal, polypropylene.
  - Amorphous (broader melt temperature range, transparent, less shrinkage, but poor wear and fatigue resistance). Examples: ABS, polystyrene, polycarbonate.
  - Note that many thermoplastics are a mixture of amorphous and crystalline properties.

# Engineering Materials (Ctd)

- Note also that the majority of thermoplastics are commodity plastics such as film, sheet, tubes, bottles, and food packages.
- Thermoset Plastics
  - Properties: higher temperature use, minimum creep, harder surface, and more rigidity.
  - Examples: epoxies, polyesters, polyurethanes, urea-formaldehyde, phenolics
- For both thermoplastics and thermoset plastics, their properties can be modified by additives, reinforcements, or combinations with other polymers. See properties in table A9.3.

# Engineering Materials (Ctd)

- **3- Ceramics:**
  - Properties: High-temperature strength, hardness, inertness to chemicals, food, and environment, resistance to wear, and low electrical and thermal conductivity.
  - They are compounds of metallic and non-metallic elements.
  - Uses of ceramics:
    - Traditional: abrasives, clay products, construction, glass, refractories, whitewares.
    - Engineering: automotive and aerospace, electronics, high temperature, manufacturing, medical.

# Engineering Materials (Ctd)

- **4- Composites:**

- Unlike polymers, composites are a combination of 2 or more chemically distinct materials, enjoying the properties of both. The two main constituents of a composite material are the reinforcing fibers and the matrix
- Reinforcing fibers: glass, graphite, aramids (Kevlar), boron, and others
- Matrix: thermosets ( epoxy, polyester, phenolics,etc...), thermoplastics (PEEK, polysulfone, polyetherimide), metals (al, al-li, magnesium, titatium), ceramics (silicon carbide, silicon nitride, aluminum oxide), and carbon.

# Manufacturing Processes

- The major categories are: Casting, Bulk Deformation, Sheet Metalworking, Machining, Polymer Processing, Powder Metallurgy, and Assembly. (See figure 3.1, page 3-3).
- Other non-value added processes are inspection, testing, and quality assurance.
- **1- Casting:**
  - 1- Expandable molds: sand, plaster, ceramics
  - 2- Permanent molds: Die, permanent molds, centrifugal
  - 3- Special processes: investment, shell, vacuum casting

# Manufacturing Processes (Ctd)

- **2- Bulk Deformation:**
  - Rolling ( plates, sheets, bars, wire, seamless pipes, structural shapes, rails)
  - Forging:
    - Open die (for rough shape transformation)
    - Close die (take up internal shape of dies)
    - Heading (bolt and rivet heads)
    - Swaging or radial forging ( for sizing and pointing)
  - Extrusion and Drawing:
    - Direct (hot and cold)
    - Hydrostatic

# Manufacturing Processes (Ctd)

- **3- Sheet Metalworking:**
  - Shearing operations: Blanking, Punching, Slitting, Steel rules, Nibbling
  - Shaping operations: Drawing (shallow and deep), Bending, Tube bending, Stretching, Ironing, Rubber forming, Spinning, Peening, Explosive forming, Magnetic forming
  - Basic equipment for sheet metalworking:
    - Mechanical presses
    - Hydraulic presses
    - Pneumatic presses

# Manufacturing Processes (Ctd)

- **4- Machining:**

- The major categories are: Cutting, Abrasives, and Non-traditional
- Cutting:
  - Circular shapes: Turning, Boring, Drilling
  - Various shapes: Milling, Planing, Shaping, Broaching, Sawing, Gear forming, Gear generating.
- Abrasives:
  - Bonded: Grinding, Honing, Coated abrasives
  - Loose: Ultrasonic, Abrasive-jet, Lapping, Polishing, Buffing

# Manufacturing Processes (Ctd)

- **4- Machining (Ctd):**
  - Non Traditional:
    - Necessitated by one of the following conditions: High hardness or strength of materials, too flexible, slender or delicate to withstand cutting or grinding forces, complex shapes, very small diameter holes, high surface finish quality, localized stress in workpieces.
    - Processes: Electrical-Discharge, Chemical, ElectroChemical grinding, Laser-beam, Electron-beam.

# Polymer Processing

- The most common processes:
  - Injection Molding
  - Compression Molding
  - Transfer molding
- Injection Molding:
  - Screw-type injection molding machine. See fig. 3.2.
  - Thermoplastic materials in pellet form
  - Mold features: mold halves, sprue, gate, runners, cooling system, ejector pins
  - Design features that increase cost of production: shape complexity, uneven thicknesses, and undercuts (internal and external).

# Compression Molding

- Used for thermoset plastics
- Raw material is a slug of material called charge
- Mold is similar to mold used in injection molding, but noted absence of sprue, gate, and runners
- Design features that increase production costs: complex shapes, and external undercuts
- See fig.3.4 for typical compression molding tool.
- Machine is hydraulically driven.

# Transfer Molding

- Process quite similar to compression molding except for construction of mold
- Mold has two portion:
  - Upper portion where slug is heated and melted
  - Lower portion where molten slug is force to take up shape of mold
  - See figure 3.5 for tooling for transfer molding

# Die Casting

- Process similar to injection molding, but used for metals such as zinc, tin, lead, aluminum and copper.
- Two types of die casting machines:
  - Hot chamber: for low melting metals such as zinc, tin, and lead. Aluminum and copper cannot be die casted in a hot chamber machine.
  - Cold chamber: metal melted in a chamber separated from the machine.
- Design impact on die casting similar to design impact on injection molding.

# **DFM Guidelines for Injection Molding, Compression Molding, Transfer Molding, and Die Casting**

- These four processes follow the same transformation process steps: internal flow, cooling and solidification, then ejection from mold.

# Design Guidelines (Ctd)

- 3- Smooth and easy flow path
- 4- Avoid thick walls
- 5- Avoid uneven wall thicknesses; if needed connect thick and thin walls with a taper
- 6- For large or complex parts, a double gT2.yect

## Design Guidelines (Ctd)

- Die Casting DFM Advisor:
  - See figure 3.15
  - Cycle time of part relative to a simple 1mm thick washer
  - Tooling cost depending on existence of undercuts
  - Note that internal undercuts are not usually die cast

# DFM Guidelines for Stamped Parts

- Cost of a stamped part comes from three sources: tooling, material, and labor
- Tooling and material are the biggest cost contributors, hence efforts should be made to tackle these two sources.
- Guidelines:
  - 1- Keep number of distinct features to a minimum
  - 2- Avoid closely spaced features
  - 3- Avoid narrow cutouts and narrow projections

# DFM Guidelines for Stamped Parts (Ctd)

- 4- Keep number of bended stages to a minimum
- 5- Bend angles greater than  $90^{\circ}$  should be avoided
- 6- Side-action features should be avoided
- Stamping DFM Advisor:
  - See figure 3.26
  - Advising for two types of parts:
    - Parts with holes, ribs, and other localized features
    - Parts with bend
  - Tooling cost given in relation to a simple washer

# Assembly Process

- The two major elements of an assembly process: handling and insertion.
- Handling can be done manually or by automatic means:
  - Manual: reach, grasp, transport, orient, preposition for insertion, and insertion.
  - Automatic: feeder bowl, orientation devices, feed tracks, and escapement devices

# Assembly Process (Ctd)

- Qualitative Guidelines:
  - Reduce part count
  - Reduce manual handling time: avoid tangling and nesting, provide symmetry in design
  - Facilitate automatic handling: parts to be easily fed (from a feeding bowl) and oriented.
  - Design for easy insertion
- DFA Advisor:
  - See figure 3.41
  - Table provides rough time estimation

# Summary

- Designers should have a working knowledge of
  - 1- The different types of natural and engineered materials and their properties
  - 2- The most appropriate processes for the chosen materials
  - 3- The guidelines for each of the common processes used by industry
- The discussion of materials and their processing methods in this class is very preliminary. More in-depth discussion will be made later.