Manufacturing Processes
(Part 5)
F 20-1 Tool nomenclature
F 20-2 Single-point cutting tool
F 20-3 Flank and crater wear
F 20-4 Tool life vs. cutting speed
F 20-5 Hardness as a function of temperature
Cutting Tool Materials

- High-speed steels
- Cast cobalt alloys
- Carbides
- Coated carbides
- Ceramics
- Cubic boron nitride
- Diamond
Cutting Fluids

- Cutting oils
- Emulsifiable oils
- Chemical and semichemical fluids
- Gaseous fluids
Machining

Chapter 21
Machining

• Turning
• Drilling
• Milling
• Bandsawing
• Grinding
• Nontraditional machining
Lathe Components

- Bed
- Headstock
- Tailstock
- Carriage
- Quick-change gearbox
F 21-1 Engine lathe
F 21-2 Parts of a twist drill
Common drilling operations

- Drilling
- Core drilling
- Step drilling
- Counterboring
- Countersinking
- Reaming
- Center drilling

F 21-3
Drilling Machines

• Light Duty Drill Press

• Gang Drilling
  – Two or more, light duty, single phase machines on a common base
Drilling Machines

• **Radial Drilling**
  – Arm which carries adjustable position drill head that can be raised, lowered, and pivoted around a column

• **Turret Drilling**
  – Bench and floor models with indexed drums or turrets and multiple axis capability
Milling

(a) Slab or plain milling
(b) Face milling
(c) End milling

F 21-4 Milling cutters
Milling

(a) 
(b) 
(c) 

F 21-5 Milling operations
Bandsaw

- Tooth spacing
- Tooth face
- Tooth back flank
- Tooth back clearance angle
- Gullet depth
- Tooth rake angle
- Back edge
- Body
- Width

F 21-6 Terminology
Bandsaw

(a) Raker set  (b) Wave set  (c) Straight (alternate) set

Standard tooth  Hook tooth

Skip tooth

1 in. (25.4 mm)
Grinders

- Surface
- Cylindrical and centerless
- Internal
- Universal cutter and tool grinder
<table>
<thead>
<tr>
<th>Sequence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tr>
<td>Prefix</td>
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<tr>
<td>Abrasive type</td>
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<td>Abrasive (grain) size</td>
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<td>Bond type</td>
<td></td>
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<td></td>
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<tr>
<td>Manufacturer’s record</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**51** — **A** — **36** — **L** — **5** — **V** — **23**

- Manufacturer’s symbol indicating exact kind of abrasive (use optional)
- A - Regular aluminum oxide
- TFA - Treated aluminum oxide
- 3A
- 2A
- FA
- HA
- JA
- LA
- 13A
- 36A
- WA - White aluminum oxide
- EA - Extruded aluminum oxide
- ZT - Zirconia - 25%
- YA - Special blend
- C - Silicon carbide
- GC - Green silicon carbide
- RC - Mixture silicon carbide
- CA
- BA
- DA - Mixture S/C and A/O

Soft: A B C D E F G H I J K L
Medium: M N O P Q R S T U V
Hard: W X Y Z

**Grade scale**

**F 21-10 Standard bonded-abrasive wheel**
F 21-8 Spindle grinding
F 21-9 Centerless grinding
Nontraditional Machining Processes

- Typically employed when conventional methods are incapable, impractical, or uneconomical because of special material properties, workpiece complexities, or lack of inherent rigidity.
Nontraditional Machining Processes

- Waterjet machining
- Abrasive waterjet machining
- Electrochemical machining
- Electrical discharge machining
- Laser beam machining
F 21-11 Electrical discharge machining
F 21-12 Wire EDM
Fundamentals

• Bulk metal forming
  – Rolling
  – Extrusion
  – Forging
  – Drawing

• Sheet metal forming
  – Shearing
  – Bending
  – Drawing
Bulk Metal Forming Operations

- Hot forming
  - above the recrystallization temperature

- Cold forming
  - below the recrystallization temperature

- Warm forming
  - a cross between hot and cold forming
Metal Forming Processes

- Rolling
- Hot Extrusion
- Forging
- Wire and bar drawing
# Forming Categories and Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hot Forming</th>
<th>Warm Forming</th>
<th>Cold Forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting temperature</td>
<td>Above the recrystallization temperature</td>
<td>Approximately 30–59% of the melting temperature</td>
<td>Below the recrystallization temperature</td>
</tr>
<tr>
<td></td>
<td>Approximately 60–90% of the melting temperature</td>
<td></td>
<td>Approximately 1–29% of the melting temperature</td>
</tr>
<tr>
<td>Surface finish</td>
<td>Poor</td>
<td>Average</td>
<td>Good</td>
</tr>
<tr>
<td>Dimensional accuracy</td>
<td>Poor</td>
<td>Average</td>
<td>Good</td>
</tr>
<tr>
<td>Strain hardening</td>
<td>No</td>
<td>Possibly</td>
<td>Yes</td>
</tr>
<tr>
<td>Forming force</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>
F 22-1 Hot-rolling process
F 22-2 Rolled products (AISI)
F 22-3 Direct hot extrusion

1. Extrusion
2. Die backer
3. Die
4. Billet
5. Dummy block
6. Pressing ram
7. Container liner
8. Container body
F 22-4 Indirect extrusion
Forging

F 22-5 Grain pattern
Forging

Upper die

Workpiece

Lower die

F 22-6 Open-die
Forging

(a)

(b)

(c)

F 22-7 Closed-die
Forging

F 22-8 Coining process
F 22-9 Upsetting or heading
Wire and Bar Drawing

Original diameter

Drawing die

Final diameter
Sheet Metalworking

- Shearing
- Bending
- Drawing
- Process and dies
Shearing

• Process of mechanically cutting sheet metal with the application of shear force
F 23-1 Fundamentals
Shearing Operations

• Punching
• Blanking
• Notching
• Lancing
• Dinking
Punching

F 23-2 Punching/Piercing (Wick, Benedict, and Veilleux 1984)
Blanking

Scrap skeleton

Blank

F 23-3 Blanking (Wick, Benedict, and Veilleux 1984)
Lancing

Lanced and formed, one operation

Louver

F 23-4 Lancing (Wick, Benedict, and Veilleux 1984)
Dinking

Dinking die

Workpiece

Wood block

F 23-5 Dinking
Bending

- Used in sheet metal to gain rigidity and produce a part of desired shape to perform a particular function.

  - eg. braces, brackets, supports, hinges, angles, channels
Press Brake Bending and Forming Dies

F 23-8 (Wick, Benedict, and Veilleux 1984)
Flanging

- Flange bending
- Hemming
- Roll bending
- Drawing
Straight Bend

- Bend radius ($r$)
- Length of bend
- Bend angle
- Material thickness ($t$)

F 23-6 Terminology (Wick, Benedict, and Veilleux 1984)
Straight Flange

F 23-9 (Wick, Benedict, and Veilleux 1984)
Hem Types

- Flattened hem
- Tear drop hem

F 23-10 (Wick, Benedict, and Veilleux 1984)
F 23-7 Mechanical press break (Wick, Benedict, and Veilleux 1984)
Roll-bending Machine

F 23-11 Pyramid type (Wick, Benedict, and Veilleux 1984)
Drawing

• A process of cold forming a flat precut metal blank into a hollow vessel without excessive wrinkling, thinning, or fracturing
  – eg. oil pans, cookware pots
F 23-12 (Schrader and Elshennawy, 2000)
Presses and Dies

• Are classified by one or a combination of characteristics that include the source of power: manual, mechanical, and hydraulic

• Number of slides
Press Tooling Components

- Punch holder
- Punch
- Stripper
- Die
- Die shoe
- Bolster
- Guide pins
- Bushings
- Blank
Blanking Die

F 23-13 Press tooling
Powdered Metals

Chapter 24
Powdered Metallurgy (PM)

- A metal working process for forming near-net shape, precision metal components, and shapes from metal powders
- Four basic steps: melt atomization, blending, compacting, and sintering
Melt atomization

(Step 1)

F 24-1 Melt atomization
Blending
(Step 2)

• Oversize and fine particles are filtered out
• Mixing of metal and alloy powder (if desired)
• Lubricants are added
• Binders are added
• Alloy powders are added (if desired)
Compacting
(Step 3)

• Consolidates and densifies the loose powder into a shape called a green compact. With conventional techniques, the compact has the size and shape of the finished product when ejected from the die.
Compacting
(Step 3)

F 24-2 Powdered metal tooling (Cubberly and Bakerjian, 1989)
Compaction Cycle

F 24-3 Powdered metal compaction cycle (Cubberly and Bakerjian, 1989)
Sintering
(Step 4)

• A solid state process that develops metallurgical bonds among the powder particles.

• Process is performed in a three-stage continuous furnace
Continuous Sintering Temperature Profile

F 24-4 Temperature profile (Wick, Benedict, and Veilleux, 1984)
Casting

Chapter 25
Casting

• A process in which molten metal is poured or injected into a cavity and allowed to solidify

• After solidification, the part is removed and processed for delivery
## Casting Processes

<table>
<thead>
<tr>
<th>Casting Process</th>
<th>Ductile Iron</th>
<th>Steel</th>
<th>Stainless Steel</th>
<th>Aluminum, Magnesium</th>
<th>Bronze, Brass</th>
<th>Gray Iron</th>
<th>Malleable Iron</th>
<th>Zinc, Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die</td>
<td></td>
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<tr>
<td>Cope and drag</td>
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<td>Permanent mold</td>
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<td>Plaster mold</td>
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<td>Centrifugal</td>
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</tbody>
</table>
Casting Advantages

• Casting allow the manufacture of parts from alloys that are difficult to machine or weld
• Complex shapes are easier to produce by casting than by other processes
• Parts with internal cavities are easier and more economical to produce by casting
Typical Cored Casting

F 25-1 (Courtesy American Foundry Society)
Casting Processes

- Multiple-use pattern/single-use mold
- Single-use pattern/single-use mold
- Multiple-use mold
Multiple-Use Pattern/Single-Use Mold

- Green sand molding: mold is compacted around a pattern with a sand-clay water mixtures.

- Shell molding: a higher degree of accuracy and surface finish than sand casting.
F 25-2 Green-Sand Mold (Wick, Benedict, and Veilleux, 1984)
1. Metal pattern is required for shell molding. Surfaces must be smoother and dimensions closer than those used by sand casting.

2. Sand and resin mixture is dumped freely onto the heated metal pattern to make the shells.

3. Heat is applied to cure the resin-sand mixture and makes a rigid, firm, easily handled shell. Each shell mold consists of two united halves—cope and drag.

4. Cured mold is ejected from the pattern plate and is ready to be assembled for casting, or can be stored for long periods without deterioration.

5. Ready for casting. The two halves of the mold (cope and drag) are bonded together, and the completed molds are ready for pouring. This is accomplished by placing the molds in a horizontal position on trays that are suspended from a moving conveyor.

6. Casting. As the molds pass by a pouring station, which also is on a moving belt, they are filled with molten iron (poured).

7. Gate of castings emerges from the expendable resin-sand shells.

F 25-3 Shell Molding (Courtesy Foundry Division, Eaton Corp.)
Single-Use Pattern/Single-Use Mold Process

• Investment casting
• Evaporative (Lost Foam) casting

  – In both processes, the pattern and mold can only be used once.
F 25-5 Evaporative Pattern (Lost Foam) Process
(Wick, Benedict, and Veilleux, 1984)
Multiple-Use Mold Process

• Permanent mold casting: molten metal poured under pressure of a gravity head into a static mold. (Used for lighter nonferrous metals)

• Die casting: Molten metal is forced under pressure into molds or dies. (Low melting temperature alloys: aluminum, zinc, and magnesium)
1. Apply refractory mold coating to internal sections of preheated mold sections

2. Set mechanical, shell, or sand cores as required, and close mold

3. Pour properly heated aluminum into sprue openings

4. After casting has solidified, remove from mold

F 25-6 Permanent-Mold Aluminum Casting (Wick, Benedict, and Veilleux, 1984)
Hot Chamber Die Casting

Cold Chamber Die Casting

F 25-7 Die Casting Machines (Schrader and Elshennawy, 2000)
Welding

- Definition: Permanent joining of two materials by coalescence
- Welding categories
  - Oxyfuel gas welding
  - Arc welding
  - Electric resistance welding
  - Solid state
  - Unique processes
Oxyacetylene Welding

- Performed with or without a filler at approximately 6300 degrees
Oxyacetylene Welding

F 26-1 (Wick and Veilleux, 1987)
F 26-2 Types of oxyacetylene flames. (Wick and Veilleux, 1987)
Oxyfuel Gas Cutting

• Used to cut steel up to 2” in thickness

• A thermal cutting process of rapid burning or oxidation of iron in the presence of high-purity oxygen.
F 26-3 Oxyfuel cutting (Wick and Veilleux, 1987)
Arc Welding

• Process: an electric arc extends from an electrode to a grounded work piece creating welding temperatures around 12,000 degrees Fahrenheit
Three Most Used Arc Welding Processes

• Shielded-metal-arc welding (SMAW)

• Gas-metal-arc welding (GMAW)

• Gas-tungsten-arc welding (GTAW)
Shielded-Metal-Arc Welding (SMAW)

• Joins metals by heating with an electric arc between a consumable, flux coated electrode
• Shielding provided by decomposition of the flux
• Filler metal provided by the electrode
Shielded-Metal-Arc Welding

- Protective gas from electrode coating
- Molten weld metal
- Slag
- Solidified weld metal
- Base metal
- Electrode
- Electrode coating
- Arc
- Metal droplets

F 26-4 (Courtesy Hobart Institute of Welding)
Gas-Metal-Arc Welding (GMAW)

- Joins metals by heating with an electric arc between a continuous solid wire and work piece
- Shielding provided by an externally supplied gas
- Wire used is consumable and becomes part of the weld pool
- Also known as (MIG) welding
Gas-Metal-Arc Welding

Solid wire electrode
Shielding gas IN
Current conductor
Welding torch
Wire guide and contact tube
Gas nozzle
Shielding gas

Travel

Solidified weld metal
Arc
Molten weld metal
Work

F 26-5 (Courtesy Lincoln Electric Co.)
Gas-Tungsten-Arc Welding (GTAW)

- Joins metals by heating with an electric arc between a nonconsumable tungsten electrode and workpiece
- Shielding provided by an inert gas envelope
- Usually a filler metal is used
- Also called TIG welding
Gas-Tungsten-Arc Welding

- Welding torch
- Gas passage
- Filler rod
- Electrical conductor
- Tungsten electrode
- Shielding gas
- Solidified weld metal
- Molten weld metal
- Work

F 26-6 (Courtesy Lincoln Electric Co.)
Electric Resistance Welding

- Processes that produce a coalescence of metals from the heat obtained by the resistance to current and application of pressure
- No flux, filler, metal, or shielding is used
- Most common-spot welding
Resistance Spot Welding

Weld nugget

Electrode

Electricity

Base metal

F 26-7 Resistance spot welding
Solid-State Welding

- **Process:** A welded joint is produced without melting the parent metal or filler material.

- **Types of solid-state welding:**
  - Forging
  - Inertia
  - Diffusion
  - Ultrasound
Ultrasonic Welding (USW)

- The joining of materials by clamping the components together and applying high frequency (10,000-100,000 Hz), oscillating shear stresses parallel to the part interface.
Ultrasonic Welding Machine

F 26-8 (Wick, Benedict, and Veilleux, 1984)
Other Welding Processes

- Laser-beam
- Electron-beam
- Thermit welding
- Flash welding
Laser Beam Welding (LBW)

- A fusion joining process that produces coalescence of metals with the heat generated by the absorption of a concentrated, coherent light beam impinging on the components to be joined.
Cross Section of Laser Weld

Laser weld

Base metal
Brazing

- A process that produces coalescence of materials by heating them in the presence of a filler metal having a liquidus above 840 degrees F and below the solidus of the base metal.
Soldering

• A process that produces coalescence of materials by heating them to a suitable temperature and using a filler metal having a liquidus below 840 degrees F and below the solidus of the base material.
Adhesive Bonding

- One surface is the adhesive while the other is the adherend. The adherend is a body that is held to another body by an adhesive
Advantages of Adhesive Bonding

- Stresses are distributed uniformly over a large area
- Applicable for a wide variety of similar and dissimilar materials
- Excellent for thin and fragile materials
- Weight of assemblies can be reduced
- Can improve fatigue life
## Structural Adhesives

<table>
<thead>
<tr>
<th>Adhesive Category</th>
<th>Characteristics</th>
<th>Specific Adhesives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemically reactive</td>
<td>Undergo a curing or cross-linking reaction within the adhesive</td>
<td>Epoxies</td>
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<tr>
<td></td>
<td></td>
<td>Polyurethanes</td>
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<tr>
<td></td>
<td></td>
<td>Phenolics</td>
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<td></td>
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<td>Silicones</td>
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<tr>
<td></td>
<td></td>
<td>Anaerobics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cyanoacrylates</td>
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<tr>
<td>Evaporative</td>
<td>Curing occurs with the loss of solvent or water</td>
<td>Vinlys</td>
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<td></td>
<td>Water-based adhesives are more environmentally friendly than other adhesives</td>
<td>Acrylics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polyurethanes</td>
</tr>
<tr>
<td>Hot melt</td>
<td>Bond forms rapidly and can join most materials</td>
<td>Polylefins</td>
</tr>
<tr>
<td></td>
<td>Variable joint gaps can be filled</td>
<td>Polyamides</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polyesters</td>
</tr>
<tr>
<td>Delayed tack</td>
<td>Nontacky solids are heat-activated to produce a state of tackiness that is</td>
<td>Polystyrenes</td>
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<tr>
<td></td>
<td>retained upon cooling for periods of up to several days</td>
<td>Polyvinyl acetates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polyimides</td>
</tr>
<tr>
<td>Film</td>
<td>Must be supplied on a flexible cloth or tape</td>
<td>Nylon epoxies</td>
</tr>
<tr>
<td></td>
<td>They have a controlled glue-line thickness</td>
<td>Vinyl phenolics</td>
</tr>
<tr>
<td></td>
<td>Easy to apply</td>
<td>Elastomer epoxies</td>
</tr>
<tr>
<td>Pressure sensitive</td>
<td>Bond formation occurs by the brief application of pressure</td>
<td>Natural rubber</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Styrene-butadiene rubber</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Butyl rubber</td>
</tr>
</tbody>
</table>
Finishing

Chapter 27
Electrostatic Spraying

- In the finishing process, the application to the material particles causes them to act like small magnets when placed in the vicinity of a grounded object.
- Applying an electrostatic charge to the material particles, transfer efficiencies of 60-90% are possible.
Electrostatic Spraying

F 27-1 (Schrader and Elshennawy, 2000)
Electroplating

- In electroplating, the workpiece is made cathodic in a solution containing the ions of the metal being deposited
- Proprietary additives can be added to the plating solution to alter physical properties of the material
Electroplating Process

F 27-2 (Schrader and Elshennawy, 2000)
Plastics Processes

- Extrusion
- Blow molding
- Injection molding
- Thermoforming plastic sheet and film
- Rotational molding
- Casting
- Compression and transfer molding

Also see table 28-1, page 228 and table 28-2, page 229
Extrusion

• Extrusion is a continuous operation that forces hot plasticized material through a die opening to produce a desired shape

• Extrusion consumes more plastic materials than any other process
Most Common Extruded Materials

- Rigid and flexible vinyl
- ABS
- Polystyrene
- Polypropylene
- Polyethylene
- Nylon
- Polycarbonate
- Polysulfone
- Acetal
- Polyphenylene
Extrusion Processes

• Categorized by the general shape of the products:
  • Profile extrusion
  • Pipe extrusion
  • Sheet extrusion
  • Film extrusion
  • Filament extrusion
  • Wire coating
Extrusion Die Design

- The design has to account for the shrinkage of the material as it cools.

- The difficulty of designing increases as the product profile becomes more complex.
Extruder Components

- Hopper
- Plastic pellets
- Feed throat
- Screw
- Motor and gearbox
- Barrel
- Heaters
- Extrudate
- Adapter
- Die
- Breaker plate
- Mixing and metering section (all melt)
- Transition section (both pellets and melt)
- Feed section (all pellets)

F 28-1
Blow Molding

• A process for shaping thermoplastic materials into one piece, hollow articles by heat and air pressure
• Two methods:
  – Extrusion blow molding
  – Injection blow molding
Extrusion Blow Molding

- An extruder creates a thick tube called a parison, pinching the bottom shut. A mold then closes on the parison, pinching the bottom shut.
- Examples: milk, shampoo, pill, and squeeze bottles
Extrusion Blow Molding

1. Die head
2. Blow pin
3. Section through the parison
4. Blow pin
5. Parison

Mold halves
Pinch bars
Flash

F 28-2 (Mitchell 1996)
Injection Blow Molding

• A parison is created by injection molding.

• Then transferred to a blowing station and inflated into a desired container.

• Greatest use: carbonated soft drinks.
Three-Station Injection Blow Molding

F 28-3 (Mitchell 1996)
Injection Molding

• A versatile process for forming thermoplastic and thermoset materials into molded products of intricate shapes, at high production rates, with good dimensional accuracy

• No chemical changes take place when the material is heated or cooled; therefore, entirely physical changes take place
Molding Machine Types

- Shot size: maximum amount of material that the machine can inject per cycle (1oz-20lbs)
  - Small: under 100 tons
  - Medium: 100-2,000 tons
  - Large: 2000 tons plus
- Clamp tonnage: amount of force machine can generate to squeeze a mold together
  - Small: under 100 tons
  - Medium: 100-2,000 tons
  - Large: 2000 tons plus
Reaction Injection Molding (RIM)

- A form of injection molding that brings temperature and ratio-controlled, liquid reactant streams together under high pressure impingement mixing to form a polymer directly into the mold
- Advantages: design flexibility, lower energy requirements, pressures, tooling costs, capital investment
Thermoforming Plastic Sheet and Film

• Consists of heating a thermoplastic sheet to its processing temperature and forcing the hot, flexible material against the contours of a mold

• Most common: vacuum forming
Vacuum Forming

F 28-5 (Mitchell, 1996)
Thermoforming Advantages

- Low cost for machinery and tooling
- Low internal stresses and good physical properties
- Capability of being predecorated, laminated, or coextruded
- Capability of forming light, thin, and strong parts for packaging
- Capability of making large one piece parts
Thermoforming Disadvantages

• Higher cost of using sheet or film

• Trimming the finished part

• Controlling the thinning of the sheet
Rotational Molding

• A process for forming hollow plastic parts by the principle that finely divided plastic material becomes molten in contact with a hot metal surface and then takes the shape of that surface.

• Less expensive than for injection molds, which have to withstand tremendous pressures
Turret-type Rotational Molding Machine

F 28-6 (Mitchell, 1996)
Casting

- Casting processes are applicable to some thermoplastic and thermosets.
- These materials can be cast at atmospheric pressure while using inexpensive molds to form large parts with section thicknesses that would be impractical to produce other manufacturing processes.
Compression and Transfer Molding

- Thermoset molding compounds are placed in a mold (hardened steel), are first heated to plasticize and cure the material, then placed under pressure to form the desired shape.

- Mold categories
  - Flash-type
  - Semi-positive
  - Positive
Thermoset Materials Used in Compression Molding

- Phenolic
- Urea
- Melamine
- Melamine-phenolic
- Diallyl phthalate
- Alkyd
- Polyester
- Epoxy
- Silicones
Composite Processes

Chapter 29
Composite Processes

- Laminating
- Filament Winding
- Pultrusion
- Resin Transfer Molding
Laminating

- Used for comparatively flat pieces
- Process started with a prepreg material (partially cured composite) with the fibers aligned parallel to each other
- A pattern and the prepreg material is then stacked in layers into the desired laminate geometry
Filament Winding

- Used for making tubes and other cylindrical structures: pressure bottles and missile canisters
- Glass fibers made of filaments are drawn though a resin bath and wound onto a rotating mandrel
Filament Winding Process

1. Fiberglass roving
2. Resin bath (catalyzed)
3. Mandrel

Oven or room-temperature cure

F 29-1 (Mitchell, 1996)
Pultrusion

- Used for parts with constant cross-sectional shapes: tubing, channels, I-beams, Z-sections, and flat bars
- Equivalent of metals extrusion
- Process consists of transporting continuous fiber bundles through a resin matrix bath and then pulling through a heated die
Pultrusion Machine

F 29-2 (Mitchell, 1996)
Resin Transfer Molding (RTM)

- Fills a niche between hand manufacturing lay-up or spray-up of parts an compression molding in matched metal molds
- The process consists of two piece matched cavity molds that are used with one or multiple injection points and breather holes
- Advantages: faster cycle times and less labor costs
Ceramic Materials

- Glasses
- Clays
- Crystalline Ceramic Powders
Glass Processes

• Begins with molten glass at approximately 2,200 degrees Fahrenheit
• Techniques
  – Glass blowing (light bulbs)
  – Flat sheets
  – Glass fibers (insulation)
  – Heat treating (tempered glass)
  – Annealing (remove residual stress)
## Tempered Glass Cross Section

<table>
<thead>
<tr>
<th>Compression</th>
<th>Tension</th>
<th>Compression</th>
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Clay Processes

- Casting
- Plastic forming
- Dry powder pressing
Casting

• Clay prepared as a slip which is a suspension of clay in water
• Chemicals added to the slip to keep it in suspension
• Slip casting – pouring of slip into a plaster mold (most common)
• Plaster molds rapidly draw the water out of the slip
• The slip is emptied out of the mold - E.G. Toilet tank
Plastic Forming

• Pressing
• Throwing (using a potter’s wheel)
• Jiggering (used to form a plate)
• Extrusion (used to manufacture clay pipe and drainage tile)
Jiggering

- Metal template
- Clay
- Plaster mold
Dry Powder Pressing

- Compacts clay powder with a low moisture content between two dies
- High dimensioning accuracy process
- Lower cycle time and higher quality than jiggering in dinner plate production
Crystalline Ceramic Powder Processing

- Crystalline ceramics, very hard and brittle
- High melting points
- Compacted as powder into shape
- Dry pressing with a ram
- *Isostatic pressing* uses flexible cover and pressurized hydraulic oil
- Example: automotive spark plugs
Processing Parts After Casting

- Drying – removing excessive moisture prior to firing to prevent cracking in the kiln
- Firing – causes the oxide particles in the part to bond and reduce the porosity and increases strength and hardness
- Finishing techniques
  - Glazing most used, improves strength and appearance by forming a smooth glassy coating
  - Painting and decals are applied prior to glazing
Printed circuit Board Fabrication and Assembly

Chapter 31
Fabriaction

- A schematic capture of the electronic design layout is transformed into a board layout with the use of a (CAD) program
- Circuit boards are typically copper that is laminated to a fiberglass substrate
- Types: single sided, double sided, and multi layered configuration
Six Layer Circuit Board

- Typical selective tin/lead plating or solder-resist coating on outer layers
- Copper layers
- Typical FR-4 glass/epoxy substrate
- Semi-cured glass/epoxy resin
Plated Through Holes (PTH)

Plated through-hole connects layers 1, 4, and 6

Copper layers
1. Topside, circuit and pad layer
2. Power layer
3. Signal layer a
4. Signal layer b
5. Ground layer
6. Bottom side, circuit and pad layer

Conductive inner layer connection to a plated through hole
Circuit Board Assembly

• Through hole technology (THT)

• Surface mount technology (SMT)
Through Hole Technology Components

(a) Axial-lead resistor   (b) Radial-lead transistor
(c) Dual in-line package (DIP)   (d) DIP socket
Automatic Axial-Lead Insertion Machine
Surface Mount Technology Devices

(a) Small-outline transistor (SOT)  (b) Ball-grid array (BGA)

(c) Small-outline IC (SOIC)  (d) Flat pack (FP)

F 31-5 (Boothroyd and Dewhurst, 1994)
Advantages of Surface Mount Technology (SMT)

• Holes not required for assembly

• Surfaces on both sides provide greater surface area to place surface mount devices (SMDs)