Manufacturing Processes

Over the next few lectures, we will take a closer look at different classes of manufacturing processes.

- Casting
- Forming
- Machining
- Metal Fluid Fluids
- Joining/Welding
- Grinding
- Surface Coatings
- Micromanufacturing/Electronics mfg.
- Non-traditional manufacturing
Types of Casting Processes

- Sand Casting
- Investment Casting
- Permanent Mold Casting
- Die Casting

Great site at:
Casting Basics

- Molten alloy is made to flow into a mold cavity
- Solidification occurs

Casting processes can produce:

- Components with complex shapes
- Components with desired properties, e.g., mechanical, chemical, electrical, magnetic, and optical
Alloy Basics

Casting -- Metal Alloys -- 70% of the elements in the periodic table are metals (luster, malleability, high thermal and electrical conductivity).

Alloy: mixture or solution of matter that has metallic properties. Examples of alloy families follow:

- **Brass** - Copper (Cu) with zinc (Zn)
- **Bronze** - Copper (Cu) with tin (Sn)
- **Steel** - Iron (Fe) and under 2% carbon (C)
- **Cast Iron** - Iron with 2-6% C
- **Solder** - Often lead (Pb) with tin (Sn).
Example Alloys

- Cu-5%Zn-5%Sn-5%Pb bronze for valves and fittings
- Ti-6%Al-4%V common titanium alloy for aerospace
- Fe-18%Cr-8%Ni-1%Mn nonmagnetic stainless steel for applications requiring resistance to corrosion and oxidation
- Al-4.5%Cu nominal composition for series of aluminum aerospace alloys
- 390Al -- Al-17%Si (hypereutectic alloy)
Aluminum Casting

- Automotive advantage -- 2.9 times lighter than iron

- Processes
  - Die casting
  - Precision sand casting
  - Semi-permanent mold
  - Lost foam

- Environmental issues
  - Air emissions & Odors
  - Solid waste
  - Water usage
Magnesium Casting

- **Automotive advantage**
  - 4.5 times lighter than iron
  - 1.5 times lighter than aluminum

- **Environmental issues**
  - SF6 as cover gas for both aluminum and magnesium casting -- a replacement is needed. (SO2 as replacement?)
  - Fire hazards in machining and processing
Casting Processes

Classified based on:

- Mold material
- Method for moving molten alloy into the mold cavity
- Method (type of pattern) used to shape the mold cavity
Casting Nomenclature

- Sprue
- Parting Line
- Core
- Runner
- Gate
- Cope Flask
- Mold Cavity
- Drag Flask
- Risers
- Sand
# Types of Casting Processes

<table>
<thead>
<tr>
<th>Casting Process</th>
<th>Mold Material</th>
<th>Pattern Material</th>
<th>Method to Fill Mold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>Sand (SiO2), clay water, oil, or resin.</td>
<td>Reusable: wood, fiberglass, metal, alloy Expendable: polystyrene</td>
<td>Usual: gravity Alternate: pressurized</td>
</tr>
<tr>
<td>Investment</td>
<td>Monolithic: plaster Shell: silica, zircon, alumina, zirconia</td>
<td>Expendable: wax</td>
<td>Gravity, gas pressure</td>
</tr>
<tr>
<td>Permanent Mold</td>
<td>Steel, iron, copper, graphite</td>
<td>None, cut in mold</td>
<td>Gravity</td>
</tr>
<tr>
<td>Die</td>
<td>Copper, steel</td>
<td>None, cut in mold</td>
<td>High pressure</td>
</tr>
</tbody>
</table>
Casting Steps

- Pattern Making. Many casting operations utilize a pattern to form the mold. This casting step is associated with the production of the pattern.
- Mold and Core Preparation and Pouring. Mold and core preparation refers to the activity of creating a cavity into which molten metal will be poured.
- Furnace Charge Preparation and Metal Handling. This step refers to the task of heating the raw material and transporting the molten raw material to the mold.
- Shakeout, Cooling, and Sand Handling. This is the act of removing the cast part from the mold, and reclaiming the used sand for future molds.
- Quenching, Finishing, Cleaning, and Coating. A cast component often receives additional treatment to improve its appearance or metallurgical properties.
Sand Casting Comments

- “Sand” is mixture of beach sand (SiO2), clay (finely divided silicates), and binder (polar molecule such as water or oil, or organic resins). Other additives: sea coal, wood flour, dextrin, and sulfur

- Sand molds generally formed in flasks (top segment - cope & bottom flask - drag)

- Planes of separation: termed parting lines.

- Molding sand compacted into the flask around pattern -- pattern removed. Draft angle
Cores & Gating

- Used to form internal shapes and dimensions (mold cavity defines the external shape)

- Cores formed from similar materials as mold -- inserted in mold cavity after the pattern is removed
  - Mixing of core and mold materials

- Gating system -- channels for molten alloy to reach and fill the mold cavity

- Risers: reservoirs of molten alloy to compensate for solidification shrinkage
Investment Casting

- Surrounding an expendable pattern (e.g., lost wax) with a heat resistant mold (e.g., ceramic)

- Removing (by melting or vaporizing) the pattern (e.g., furnace)

- Pour molten alloy into mold

- Because pattern is removed as a fluid, “parting” not required for pattern withdrawal -- reentrant angles

- Mold materials: plaster, silica, alumina, slurries, etc.
Permanent Mold Casting

- Mold cavity cut directly into material (graphite, metal, or alloy). Pattern not required
- Gravity casting
- Mold coatings reduce erosion of the molds
- Water and air cooling channels in mold wall
Die Casting

- Alloy injected into mold cavity at high pressure

- Traditionally applied to large production runs of low melting alloys, e.g., aluminum, zinc, and magnesium alloys -- die molds: steel

- Mold coatings

- High pressure: thin sections & fine surface detail
Lost Foam Process

- Molding material (frequently silica sand) rammed around expanded polystyrene (EPS) patterns
- Molten alloy poured directly into the mold -- without removing the pattern
- Heat of alloy causes polystyrene to melt/vaporize
- Gases migrate through the permeable mold material
- Accurate patterns may be made with a die -- combine patterns with adhesives
Wastes & Resources

- Material Inputs
- Air Emissions
- Wastewater
- Residual Wastes
Emissions

Iron Foundry Process Flow Sources of Emissions

- Metals
- Coke
- Fluxes
- Metal Melting
- Gas and Particulate Emissions
- Cupola
- Gas and Particulate Emissions
- Shipping
- Ductile Iron Inoculation
- Dust and Gases
- Return Sand
- Finishing
- Dust
- Casting Shakeout
- Cooling and Cleaning
- Sand Preparation
- Induction
- Dust
- Return Sand
- Spill Sand
- Gases
- Pouring
- Gases
- Cores
- Core Making
- Core Sand and Binder
<table>
<thead>
<tr>
<th>Sub-Process</th>
<th>Material Inputs</th>
<th>Air Emissions</th>
<th>Wastewater</th>
<th>Residual Wastes</th>
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<tbody>
<tr>
<td>Pattern Making</td>
<td>Wood, wax, metal, plastic, polystyrene</td>
<td>VOCs from glues, epoxies, and paints</td>
<td>Little wastewater</td>
<td>Scrap pattern materials</td>
</tr>
<tr>
<td>Green Sand Molding</td>
<td>Green sand and chemically-bonded sand cores</td>
<td>Particulates, metal oxide fumes, CO, organic compounds, hydrogen sulfide, SO2, and nitrous oxide. If chemically bonded cores are used: benzene, phenols, &amp; other hazardous air pollutants (HAPs).</td>
<td>Wastewater containing metals, elevated temperature, phenols, &amp; other organics from wet dust collection systems and mold cooling water</td>
<td>Waste green sand and core sand potentially containing metals</td>
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<tr>
<td>Chemical binding systems</td>
<td>Sand and chemical binders</td>
<td>Particulates, metal oxide fumes, carbon monoxide, ammonia, hydrogen sulfide, hydrogen cyanide, sulfur dioxide, nitrogen oxides, and other HAPs.</td>
<td>Scrubber waste water with amines or high or low pH; &amp; wastewater containing metals, elevated temperature, phenols, and other organics from wet dust collection systems and mold cooling water</td>
<td>Waste mold and core sand potentially containing metals and residual chemical binders</td>
</tr>
<tr>
<td>Lost foam</td>
<td>Refractory slurry, polystyrene</td>
<td>Particulates, metal oxide fumes, and HAPs</td>
<td>Little wastewater</td>
<td>Waste sand &amp; refractory material potentially containing metals and styrene</td>
</tr>
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Environmenally Responsible Design & Manufacturing (MEEM 4685/5685)  
Dept. of Mechanical Engineering - Engineering Mechanics  
Michigan Technological University  
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<tr>
<td>Furnace Charge Prep. and Metal Melting</td>
<td>Ingots, scrap, returned castings, fluxing agents, ladles &amp; other refractory materials</td>
<td>Products of combustion, oil vapors, particulates, metal oxide fumes, solvents, hydrochloric acid</td>
<td>Scrubber wastewater w/ high pH, slag cooling water with metals, non-contact cooling water &amp; wastewater containing metals if slag quench utilized</td>
<td>Spent refractory material maybe containing metals &amp; alloys, dross &amp; slag potentially containing metals</td>
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<tr>
<td>Shakeout, Cooling, and Sand Handling</td>
<td>Water and caustic for wet scrubbers</td>
<td>Dust and metallic particulates, VOCs from thermal sand treatment systems</td>
<td>Wet scrubber wastewater with high/low pH or amines, contact cooling water with elevated temperatures, metals and mold coating</td>
<td>Waste foundry sand and dust from collection systems, metals</td>
</tr>
<tr>
<td>Quenching, Finishing, Cleaning, and Coating</td>
<td>Paint and rust inhibitor, raw castings, water, steel shot, solvents</td>
<td>VOCs, dust and metallic particulates</td>
<td>Waste cleaning and cooling water with elevated temperature, solvents, oil and grease, and suspended solids</td>
<td>Spent containers and solvents, steel shot, metallic filings, dust and wastewater treatment sludge</td>
</tr>
</tbody>
</table>
Seacoal Replacement -- CERP

- THC/ref to Undecane
- Total HAPs
- Benzene

- Greensand Baseline
- Product A
- Product B
- Product C
- Product D