Lecture #30

ERDM

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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:
http://www.engr.uconn.edu/vc/projects/s99-151/proj2/pindex.html

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**

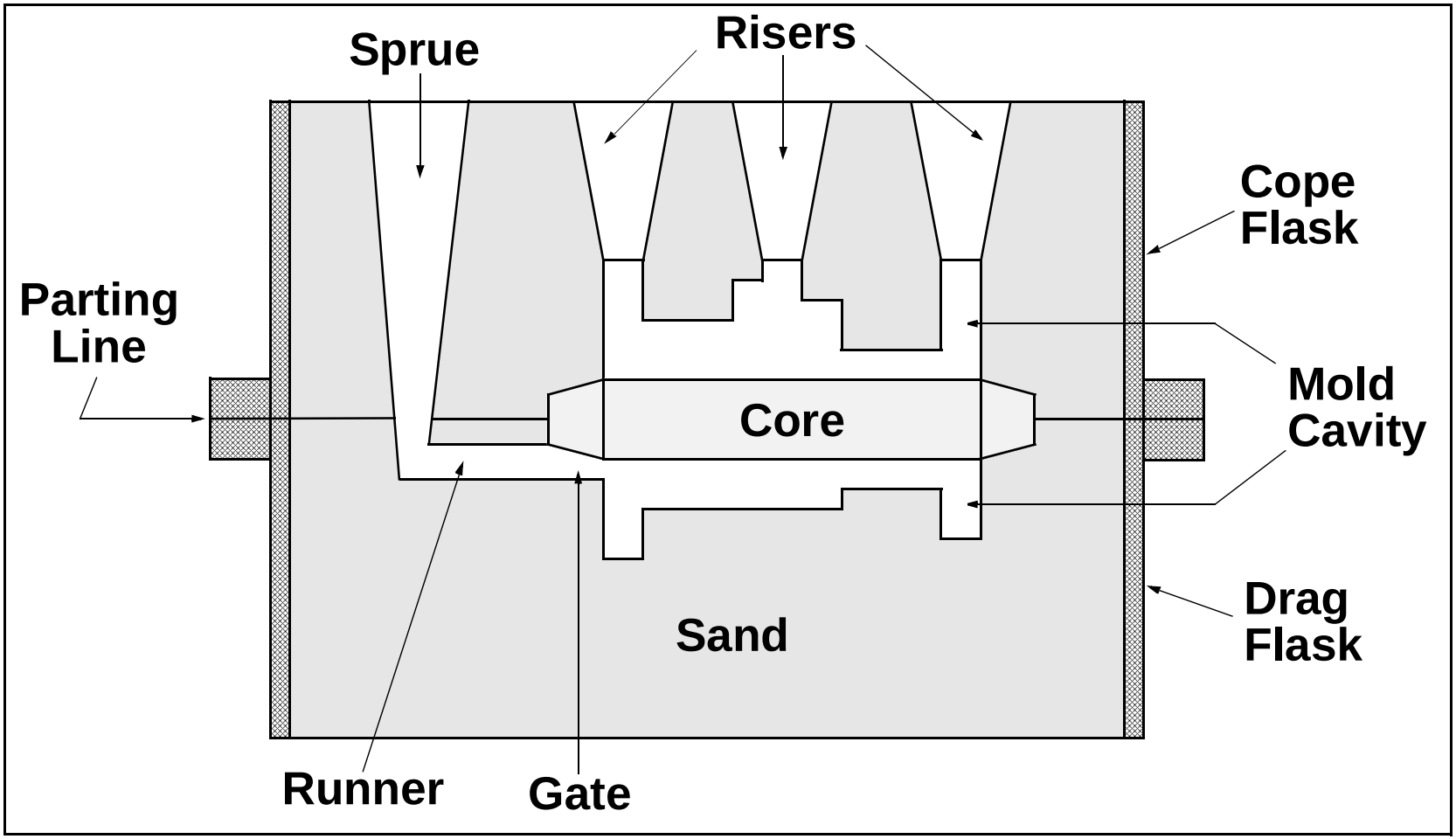
- **Environmental issues**
  - **SF6 as cover gas for both aluminum and magnesium casting -- a replacement is needed. (SO2 as replacement?)**
  - **Fire hazards in machining and processing**

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



Types of Casting Processes

Casting Process	Mold Material	Pattern Material	Method to Fill Mold
Sand	Sand (SiO_2), clay water, oil, or resin.	Reusable: wood, fiberglass, metal, alloy Expendable: polystyrene	Usual: gravity Alternate: pressurized
Investment	Monolithic: plaster Shell: silica, zircon, alumina, zirconia	Expendable: wax	Gravity, gas pressure
Permanent Mold	Steel, iron, copper, graphite	None, cut in mold	Gravity
Die	Copper, steel	None, cut in mold	High pressure

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**

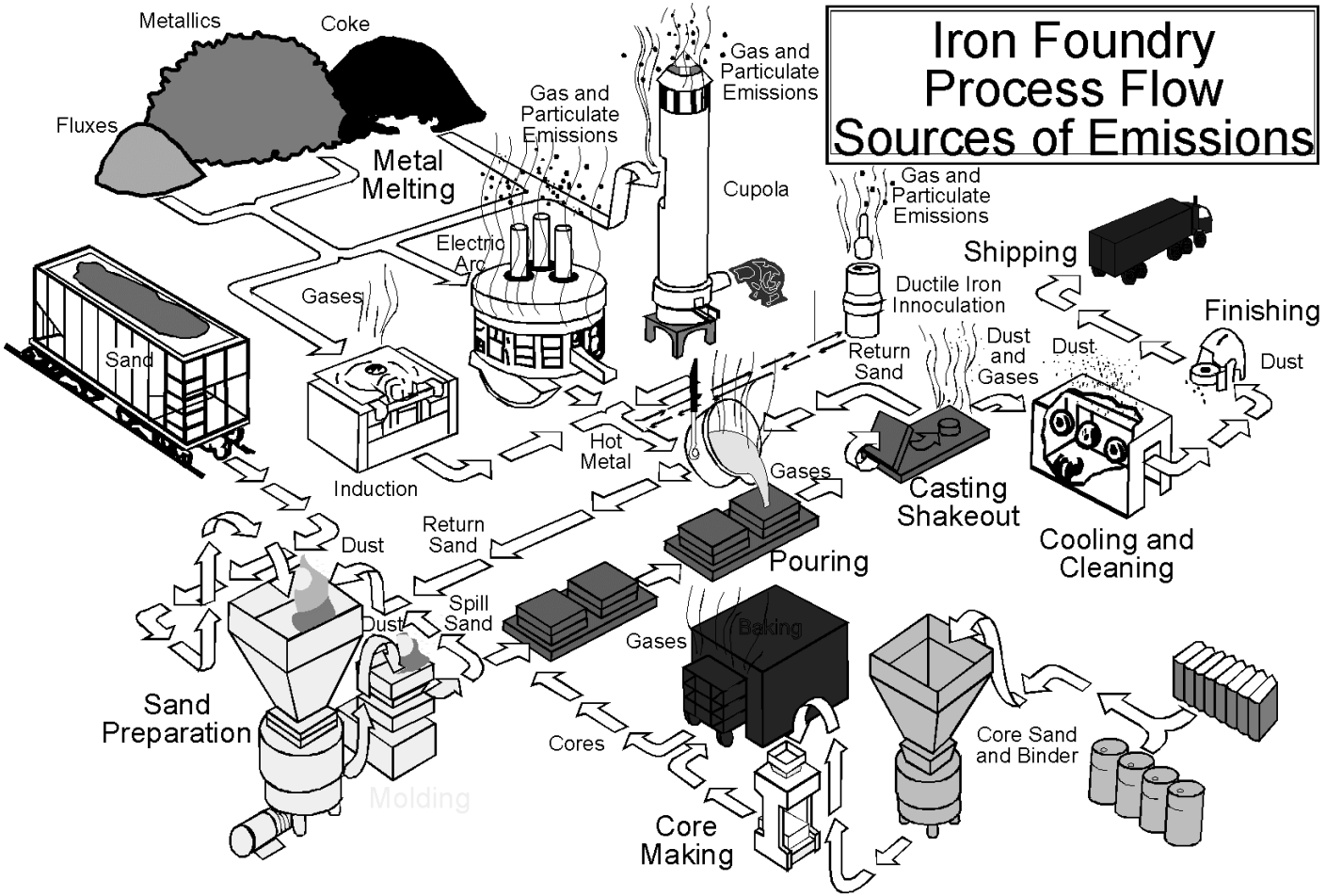
Lost Foam Process

- **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



Sub-Process	Material Inputs	Air Emissions	Wastewater	Residual Wastes
Pattern Making	Wood, wax, metal, plastic, polystyrene	VOCs from glues, epoxies, and paints	Little wastewater	Scrap pattern materials
Green Sand Molding	Green sand and chemically-bonded sand cores	Particulates, metal oxide fumes, CO, organic compounds, hydrogen sulfide, SO2, and nitrous oxide. If chemically bonded cores are used: benzene, phenols, & other hazardous air pollutants (HAPs).	Wastewater containing metals, elevated temperature, phenols, & other organics from wet dust collection systems and mold cooling water	Waste green sand and core sand potentially containing metals

Sub-Process	Material Inputs	Air Emissions	Wastewater	Residual Wastes
Chemical binding systems	Sand and chemical binders	Particulates, metal oxide fumes, carbon monoxide, ammonia, hydrogen sulfide, hydrogen cyanide, sulfur dioxide, nitrogen oxides, and other HAPs.	Scrubber waste water with amines or high or low pH; & wastewater containing metals, elevated temperature, phenols, and other organics from wet dust collection systems and mold cooling water	Waste mold and core sand potentially containing metals and residual chemical binders
Lost foam	Refractory slurry, polystyrene	Particulates, metal oxide fumes, and HAPs	Little wastewater	Waste sand & refractory material potentially containing metals and styrene

Sub-Process	Material Inputs	Air Emissions	Wastewater	Residual Wastes
Furnace Charge Prep. and Metal Melting	Ingots, scrap, returned castings, fluxing agents, ladles & other refractory materials	Products of combustion, oil vapors, particulates, metal oxide fumes, solvents, hydrochloric acid	Scrubber wastewater w/ high pH, slag cooling water with metals, non-contact cooling water & wastewater containing metals if slag quench utilized	Spent refractory material maybe containing metals & alloys, dross & slag potentially containing metals

Sub-Process	Material Inputs	Air Emissions	Wastewater	Residual Wastes
Shakeout, Cooling, and Sand Handling	Water and caustic for wet scrubbers	Dust and metallic particulates, VOCs from thermal sand treatment systems	Wet scrubber wastewater with high/ low pH or amines, contact cooling water with elevated temperatures, metals and mold coating	Waste foundry sand and dust from collection systems, metals
Quench-ing, Fin-ishing, Cleaning, and Coating	Paint and rust inhibitor, raw castings, water, steel shot, solvents	VOCs, dust and metallic particulates	Waste cleaning and cooling water with elevated temperature, solvents, oil and grease, and suspended solids	Spent containers and solvents, steel shot, metallic filings, dust and wastewater treatment sludge

Seacoal Replacement -- CERP