Overview of Metals

Manufacturing Processes

**Production of Iron**

**INPUT**
- Iron ore: rocks and minerals from which metallic iron can be economically extracted
- Limestone: it gathers the impurities in the iron ore to it and forms a lighter liquid that floats on top of the molten iron
- Coke: it burns causing an intense heat which removes the oxygen from the iron ore thus allowing the molten metal to trickle to the bottom of the furnace

**OUTPUT**
- Molten iron: it is poured into molds to form what is called "pig iron" billets
- Slag: it is basically metal oxides and non-iron impurities and it is removed from the top

- Some slag remains and combines with the molten iron causing the presence of non-metallic inclusions in the pig iron billets.

**Pig iron** is not used as is, it is melted again to reduce its carbon content and it is combined with other elements (silicon, nickel, manganese, chromium, molybdenum, etc.) to give the desired material (Cast Iron, Steel, Carbon Steel, Stainless Steel, Alloy steel, etc.)

After pig iron is molten again and other alloying elements are added it is poured into relatively large molds to form **INGOTS**

An **ingot** is a material, usually metal, that is cast into a shape suitable for further processing

**Manufacturing Processes**

In general, manufacturing operations and processes can be categorized as:

- Casting Processes
- Bulk Forming Processes
- Sheet-Metal Forming Processes
- Material Removal Processes
- Joining Processes
- Heat Treatment Processes
- Metal Plating Processes
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Casting
Casting is the first process required to reach to any type of products (ingots are produced by casting then they are further processed)

Casting is also used to produce some products in their final (or near final) shape:
- Pig iron is melted with other alloying elements and poured into molds of the desired shape (ingots of the desired material can also be used)
  - Permanent molds (made of metal)
  - Expendable molds (sand, shell-mold, plaster-mold, etc.)

Bulk Forming: Forging
Forging is the shaping of metal using localized compressive forces and usually it is done at high temperatures:
- Open-die forging
- Closed-die forging

Bulk Forming: Rolling
Rolling is a metal forming process in which metal stock is passed through a pair of rolls to give it a desired smaller cross-sectional dimensions (rolling is usually done at several stages)

According to temperature, rolling is classified into:
- Hot rolling (above crystallization temperature)
- Cold rolling (below crystallization temperature)

Rolling is usually used for producing:
- Plates & Sheets
- Bars

Bulk Forming: Extrusion
Extrusion is a process used to create long objects of a fixed cross-sectional profile by pushing the material through a die of the desired cross-section

Depending on the desired shape, extrusion can be done at hot or cold temperatures (usually hot)

The two basic types of extrusion are:
- Direct extrusion (material is pushed thru the die)
- Indirect extrusion (material and container move while the die is stationary)
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**Bulk Forming: Drawing**

Drawing is a process used for long products of small cross-sectional area where they are usually pulled through a die, rather than pushed as in extrusion.

 Drawing is used when the desired reduction in area is not that large and it is usually done at cold temperatures.

It is usually used for producing wirers and sometimes for plates.

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**Sheet-Metal Forming**

Sheet metal is simply metal formed into thin flat pieces and thus it can be cut, bent, stretched and formed into a variety of different shapes.

- **Roll forming** is used for long parts with constant complex cross-sections.
- **Stretch forming** is used for large parts with shallow contours.
- **Deep drawing** is used mostly for deep parts with relatively simple shapes.

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**Sheet-Metal Forming**

- **Stamping** includes a variety of operations such as punching, blanking, bending, flanging, embossing, etc. It is used for simple or complex shapes formed at high production rates.

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**Sheet-Metal Forming**

- **Spinning** is used for small or large axisymmetric parts.

- **Explosive forming** is used for very large sheets with relatively complex shapes (explosive charge is used to generate a pressure which forms the sheet-metal in the die).
Material Removal: Machining

Machining is the term used to describe a variety of material removal processes in which a sharp cutting tool is used to remove unwanted material from workpiece to achieve a desired geometry.

In general, machining operations are relatively slow and usually a cutting fluid is used to reduce friction and remove excess heat.

- Turning (A turning tool moves axially, along the side of a rotating workpiece)
- Milling (A rotating cutting tool with sharp teeth translates along the surface of the workpiece)
- Drilling (A rotating drill bit enters the workpiece axially and cuts a hole with a diameter equal to that of the tool)

Material Removal: Grinding

Grinding is usually done at very high speeds and thus generates very high temperatures.

- Grinding is a finishing process used to improve surface finish where an abrasive material rubs against the part surface removing tiny pieces of material.
- Polishing is the process of creating a smooth and shiny surface by rubbing it using very fine abrasive particles (or using a chemical action).

Material Joining: Welding

Welding is a process in which the pieces to be joined are melted at the joining interface (usually a filler material is added) then allowed to solidify to become a strong joint.

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The most commonly used welding process is Arc Welding where a power supply is used to create and maintain an electric arc between an electrode and the base material to melt metals at the welding point.

Other types of welding include:
- Gas welding
- Resistance welding
- Energy-beam welding
- Solid state welding
Material Joining

- **Soldering** is a process in which metal parts are joined together by melting and flowing a filler metal (solder) into the joint (the filler metal having a lower melting point than the workpiece).

- **Brazing** is a process in which a filler metal is heated above melting point and introduced between close-fitting surfaces by capillary action.

Soldering differs from welding in that soldering does not involve melting the work pieces.

Fastening is mechanically joining or affixing two or more objects together, usually using bolts and nuts.

- **Bolted joints** can be easily disassembled when needed.

- **Riveting** is a permanent joining method where a rivet is inserted into a hole then the end of the rivet is physically deformed such that it can not come out.

Riveting is widely used in the construction of airplanes.

Heat Treatment

Heat treatment refers to time & temperature-controlled process that is used to modify material properties (strength and ductility).

Heat treatment is one of the final steps in the manufacturing process where it removes the internal stresses in the material resulting from other manufacturing operations.

- **Annealing** is a process in which the material is softened (strength is reduced and ductility is increased).

During annealing the material is heated to a temperature above the crystallization temperature and is held at this temperature for a sufficient time then it is allowed to cool-down slowly.

Quenching is a process in which the material is made to be very hard (strength is increased and material becomes brittle).

During quenching the material is heated to a temperature above the crystallization temperature then it is cooled at a very fast rate using water or oil.

Tempering is done after quenching and it is used to reduce the hardness of the material (increase ductility).

During tempering the material is heated to some temperature below the crystallization temperature then it is cooled in still air.

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Metal Plating

Plating is a process in which a thin layer of metal is deposited on the surface of a conductive material. Plating is used to give the surface some desirable appearance or characteristic such as: corrosion resistance, improve solderability, increase hardness, reduce friction, improve paint adhesion, alter conductivity, etc.

The most widely used plating method is electroplating where the part to be plated (the cathode) and the plating material (the anode) are immersed in a solution (called an electrolyte) which allows metal ions to move by the electric field to coat the cathode.

For More Information on Manufacturing Processes