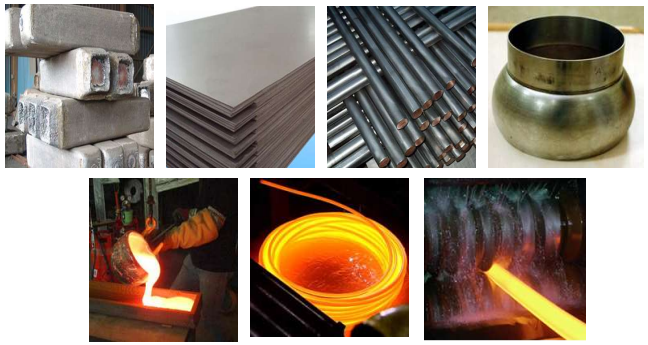
Overview of Metals Manufacturing Processes



Production of Iron

INPUT

Iron ore: rocks and minerals from which metallic iron can be economically extracted

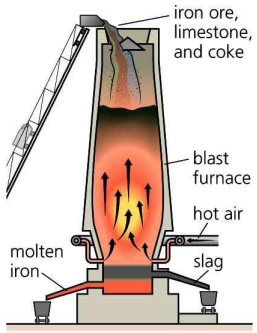
Limestone: it gathers the impurities in the iron ore to it and forms a lighter liquid that floats on top of the molten iron

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



Blast Furnace

Note: *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.)

Pig iron billets

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

Aluminum INGOTS

Stainless Steel INGOTS

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

Casting

Casting is the first process required to reach to any type of products (*ingots are produced by casting then they are further processed*)

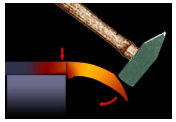
Casting is also used to produce some products in their final (*or near final*) shape

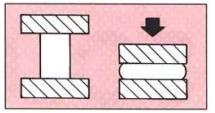
Pig iron is melted with other alloying elements and poured into molds of the desired shape (*ingots* of the desired material can also be used)

- 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

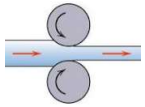




- Open-die forging
- Closed-die forging

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*)

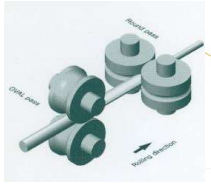


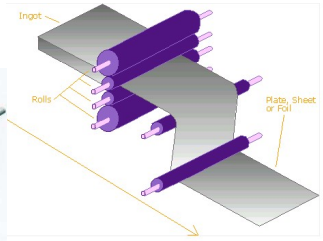
According to temperature, rolling is classified into:

- Hot rolling (*above crystallization temperature*)
- Cold rolling (*below crystallization temperature*)

Rolling is usually used for producing:

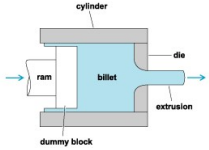
- Plates & Sheets
- Bars





Bulk Forming: Extrusion

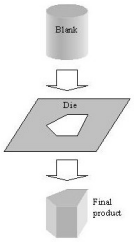
Extrusion is a process used to create long objects of a fixed cross-sectional profile by pushing the material through a die of the desired cross-section



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

The two basic types of extrusion are:

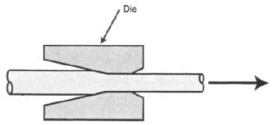
- Direct extrusion (material is pushed thru the die)
- Indirect extrusion (material and container move while the die is stationary)



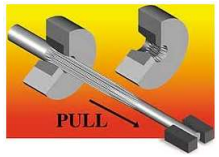
Bulk Forming: **Drawing**

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



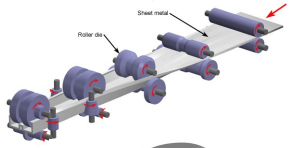
It is usually used for producing wirers and sometimes for plates

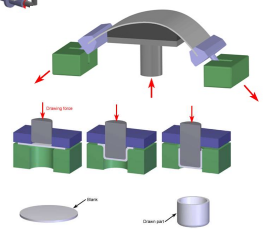


Sheet-Metal Forming

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



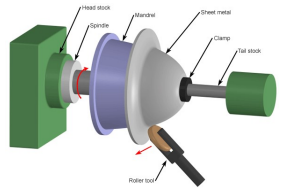


Sheet-Metal Forming

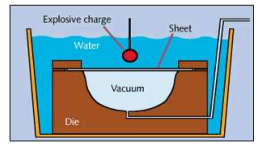
- **Stamping** includes a variety of operations such as **punching, blanking, bending, flanging, embossing**, etc. It is used for simple or complex shapes formed at high production rates

Sheet-Metal Forming

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

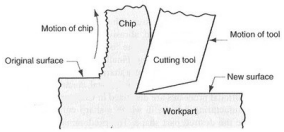


- **Explosive forming** is used for very large sheets with relatively complex shapes (*explosive charge is used to generate a pressure which forms the sheet-metal in the die*)



Material Removal: **Machining**

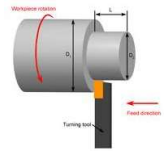
Machining is the term used to describe a variety of material removal processes in which a sharp cutting tool is used to remove unwanted material from workpiece to achieve a desired geometry



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

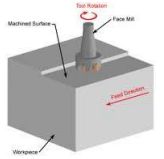
Material Removal: **Machining**

The three principal types of machining operations are:



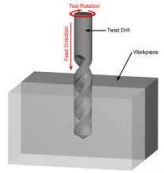
- **Turning**

  (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** is a finishing process used to improve surface finish where an abrasive material rubs against the part surface removing tiny pieces of material

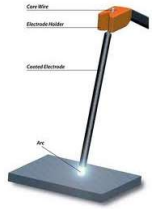
Grinding is usually done at very high speeds and thus generates very high temperatures

- **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

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:

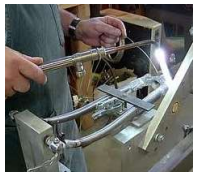
- **Gas welding**
- **Resistance welding**
- **Energy-beam welding**
- **Solid state welding**

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*)

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

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



Material Joining

- **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

Heat Treatment

- **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*)

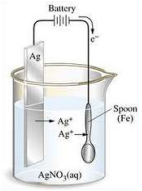
During tempering the material is heated to some temperature below the crystallization temperature then it is cooled in still air

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

- http://www.custompartnet.com/
- http://www.efunda.com/processes/