Chapter One – Introduction to Manufacturing Processes

What is Manufacturing:

The word manufacture is derived from Latin words, namely, manus (hand) and factus (make), which means made by hand.

Define of Manufacturing:

It can be defined by two ways, **technologically** and **economically**.

Technologically, manufacturing is the application of physical and chemical processes to alter or change the geometry, properties and/or appearance of a given material to make parts or products; also, it includes assembly of multiple parts to make products.

Economically, manufacturing is the transformation of materials into items of greater value by means of one or more processing and/or assembly operations. The major point is that manufacturing adds value to the material by changing its shape or properties or by combining it with other materials that have been similarly altered.

When iron ore is converted into steel, value is added.
When sand is transformed into glass, value is added.
When petroleum is refined into plastic, value is added.
When plastic is molded into the complex geometry of a patio chair, it is made even more valuable.

Figure (1-1) depicts the manufacturing definition.

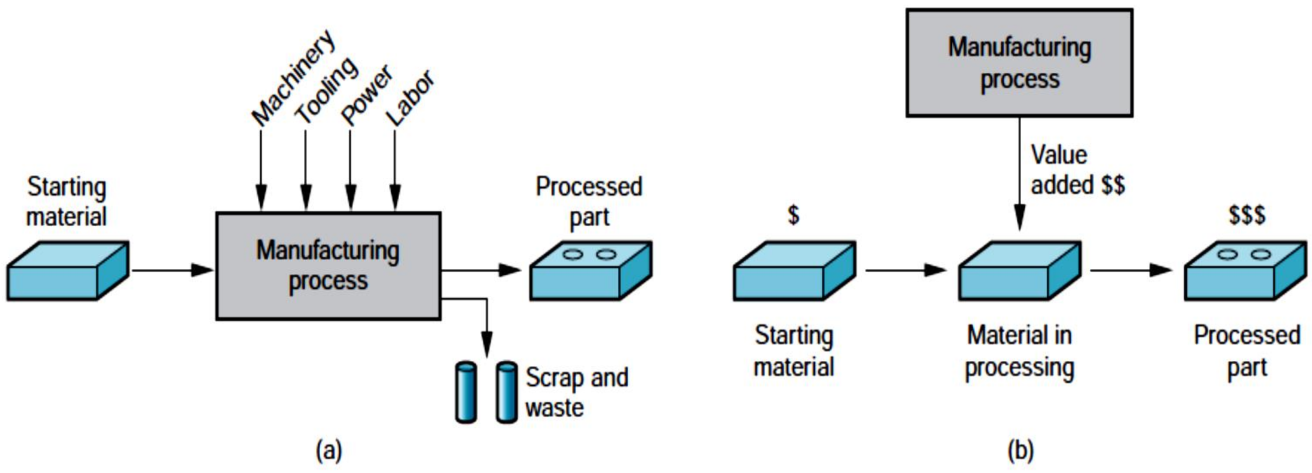

Figure (1-1) Manufacturing Definition, (a) as a technical process, and (b) as an economic process

Materials in Manufacturing:

Most engineering materials can be classified into one of four basic categories as explained in figure (1-2):
(1) Metals
(2) Ceramics
(3) Polymers
(4) Composites

(1) Metals
Metals used in manufacturing are usually alloys, which are composed of two or more elements, with at least one being a metallic element.

Ferrous Metals: Ferrous metals are based on iron; the group includes steel and cast iron. Alloys of iron and carbon form steel and cast iron. **Applications of steel** (containing 0.02%to 2.11% carbon) include construction (bridges, I-beams, and nails), transportation (trucks, rails, and rolling stock for railroads), and consumer products (automobiles and appliances).
Cast-iron applications (containing 2% to 4% carbon) include blocks and heads for internal combustion engines.

Nonferrous Metals: Nonferrous metals include the other metallic elements and their alloys. The nonferrous metals include the pure metals and alloys of aluminum, copper, gold, magnesium, nickel, silver, tin, titanium, zinc, and other metals.

(2) Ceramics
A ceramic is defined as a compound containing metallic (or semimetallic) and nonmetallic elements. Typical nonmetallic elements are oxygen, nitrogen, and carbon.

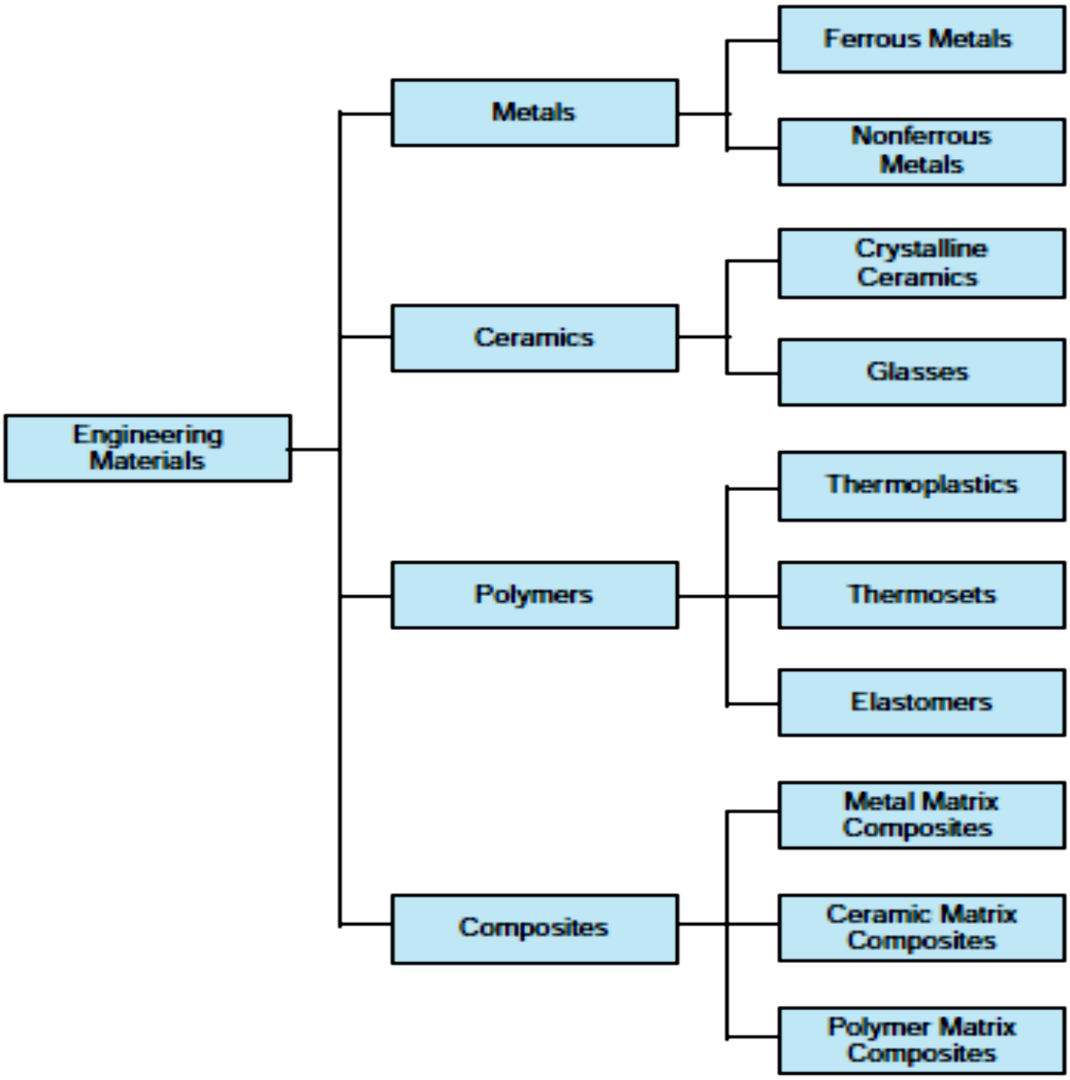

Figure (1-2) Classification of Four Engineering Materials

Clay (consisting of fine particles of hydrous aluminum silicates and other minerals used in making brick, tile, and pottery).
Silica (the basis for nearly all glass products).
Alumina and silicon carbide (two abrasive materials used in grinding).
Carbides—metal carbides such as tungsten carbide and titanium carbide, used as cutting tool materials.
Nitrides—metal and semimetal nitrides such as titanium nitride and boron nitride, used as cutting tools and grinding abrasives.
Crystalline ceramics are formed from powders and then fired (heated to a temperature below the melting point to achieve bonding between the powders).
Glass ceramics (namely, glass) can be melted and cast.

(3) Polymers

A polymer is a compound formed of repeating structural units called mers, whose atoms share electrons to form very large molecules. Polymers usually consist of carbon plus one or more other elements, such as hydrogen, nitrogen, oxygen, and chlorine.

Thermoplastic polymers can be subjected to multiple heating and cooling cycles without substantially altering the molecular structure of the polymer. Examples are polyethylene, polystyrene, polyvinylchloride, and nylon.

Thermosetting polymers chemically transform into a rigid structure on cooling from a heated plastic condition. Examples are resins, and epoxies.

Elastomers are polymers that exhibit significant elastic behavior. Examples are natural rubber, silicone, and polyurethane.

(4) Composites

A composite is a material consisting of two or more phases that are processed separately and then bonded together to achieve properties superior to those of its components. The usual structure of a composite consists of particles or fibers of one phase mixed in a second phase, called the matrix.

Properties of a composite depend on:
1. its components,
2. the physical shapes of the components,
3. the way they are combined to form the final material.

Some composites combine high strength with light weight and are suited to applications such as aircraft components, car bodies, boat hulls, tennis rackets, and fishing rods. Other composites are strong, hard, and capable of maintaining these properties at elevated temperatures, for example, cemented carbide cutting tools.

Manufacturing Processes:

The classification of manufacturing processes is presented in figure (1-3).

(1) Processing Operations

A processing operation uses energy to alter a workpart's shape, physical properties, or appearance to add value to the material. The forms of energy include mechanical, thermal, electrical, and chemical.

Shaping Operations: alter the geometry of the starting work material by various methods and apply heat, mechanical force, or a combination of these to effect a change in geometry. Common shaping processes include casting, rolling, drawing, extrusion, forging, and machining.

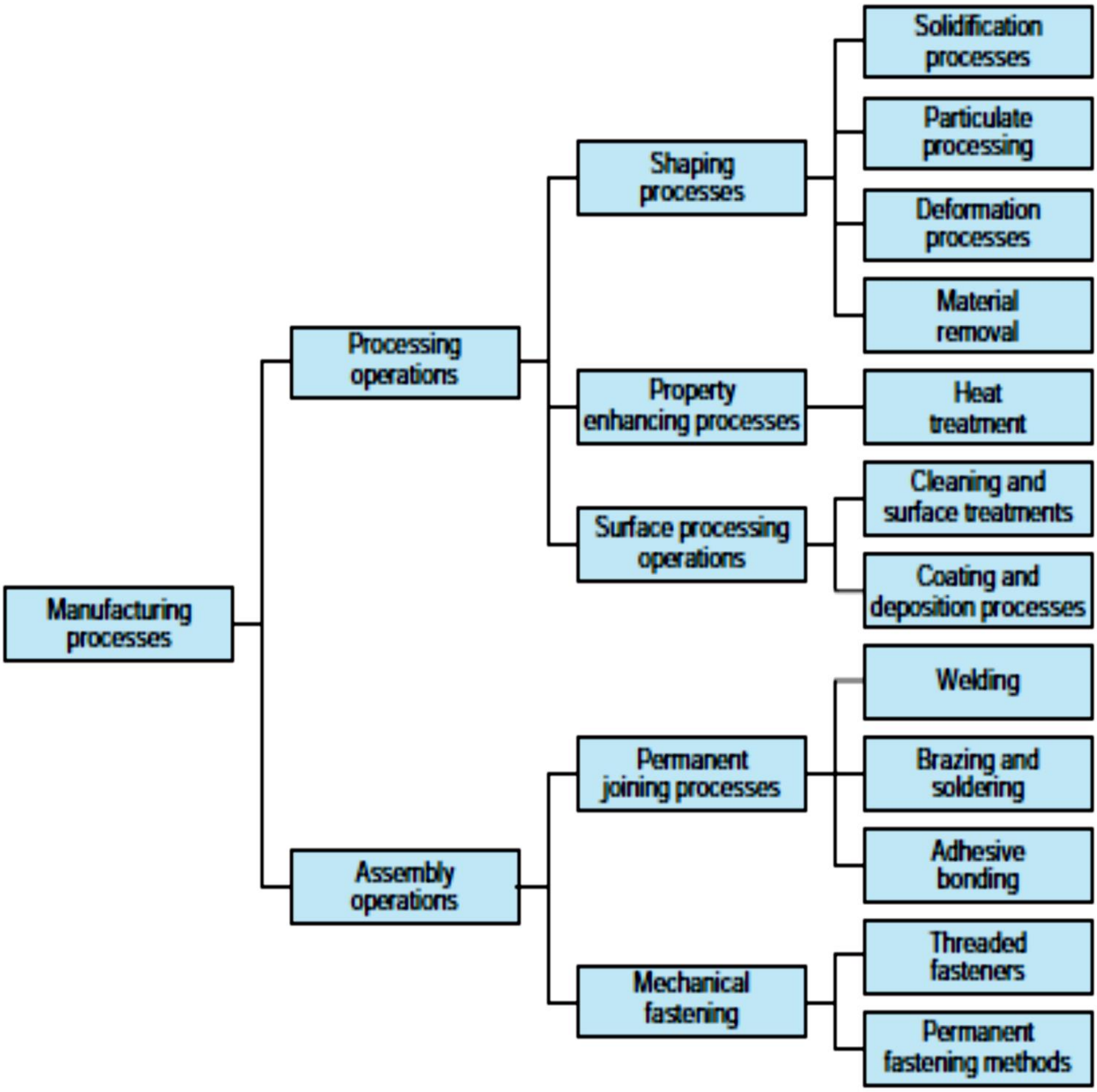

Figure (1-3) Manufacturing Processes Classification

(a) Solidification processes: in which the starting material is a heated liquid or semifluid that cools and solidifies to form the part geometry as in figure (1-4).

(b) Particulate Processing: in which the starting material is a powder of metal or ceramic, and the powders are formed by pressing and heated to bond the individual particles together and produce the desired geometry as in figure (1-5).

(c) Deformation Processes: in which the starting material is a ductile solid (commonly metal) that is deformed to shape the part by the application of forces that exceed the yield strength of the material as in figure (1-6).

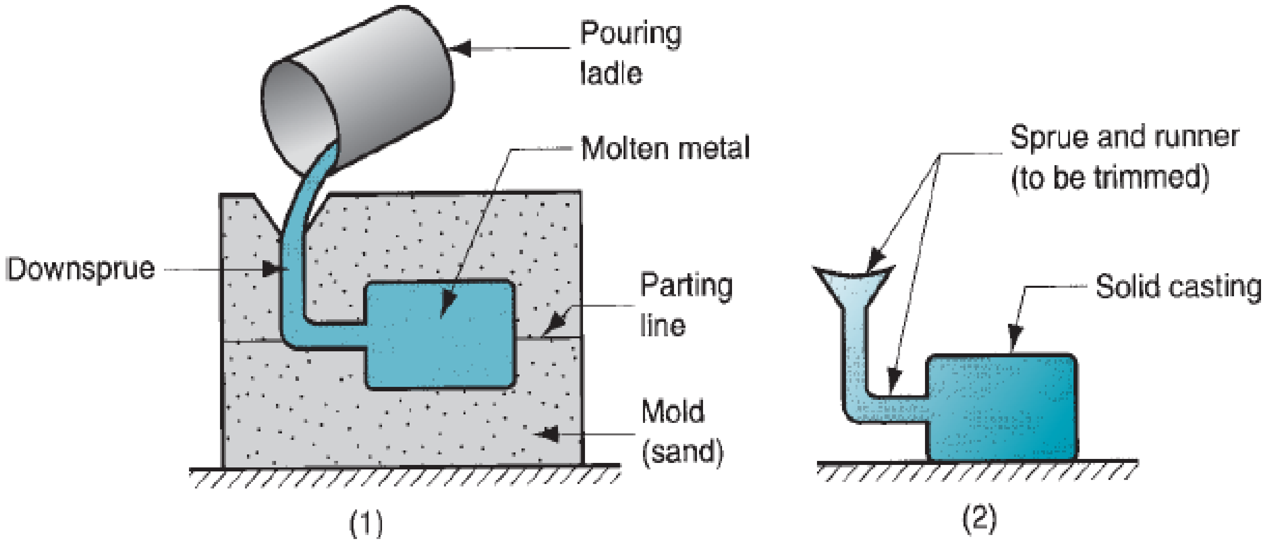

Figure (1-4) Casting Processes; (1) metal pouring, (2) solidify

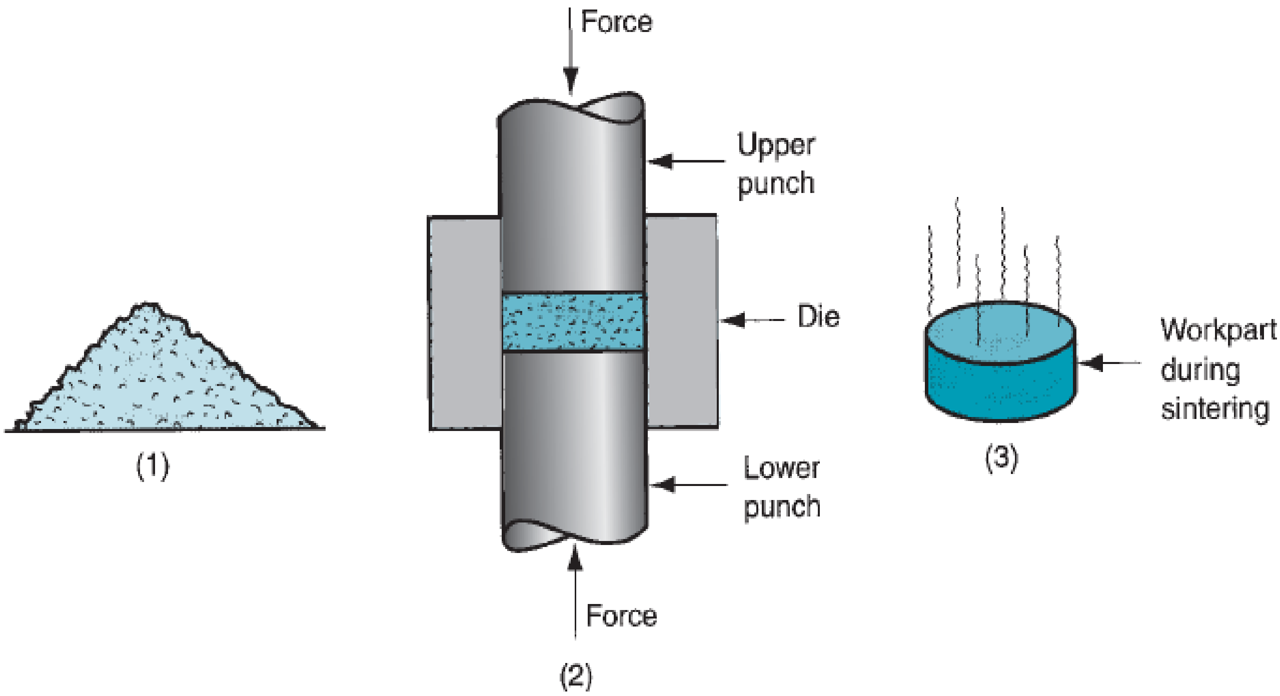

Figure (1-5) Particulate Processes; (1) powder, (2) pressing (3) sintering

(d) Material Removal Processes: are operations that remove excess material from the starting workpiece (ductile or brittle) so that the resulting shape is the desired geometry. The most important processes in this category are machining operations such as turning, drilling, and milling that are performed using cutting tools, as shown in Figure (1-7).

Also, Grinding operations are added to removal processes.

There are **nontraditional material removal processes** because they use lasers, electron beams, chemical erosion, electric discharges, and electrochemical energy to remove material.

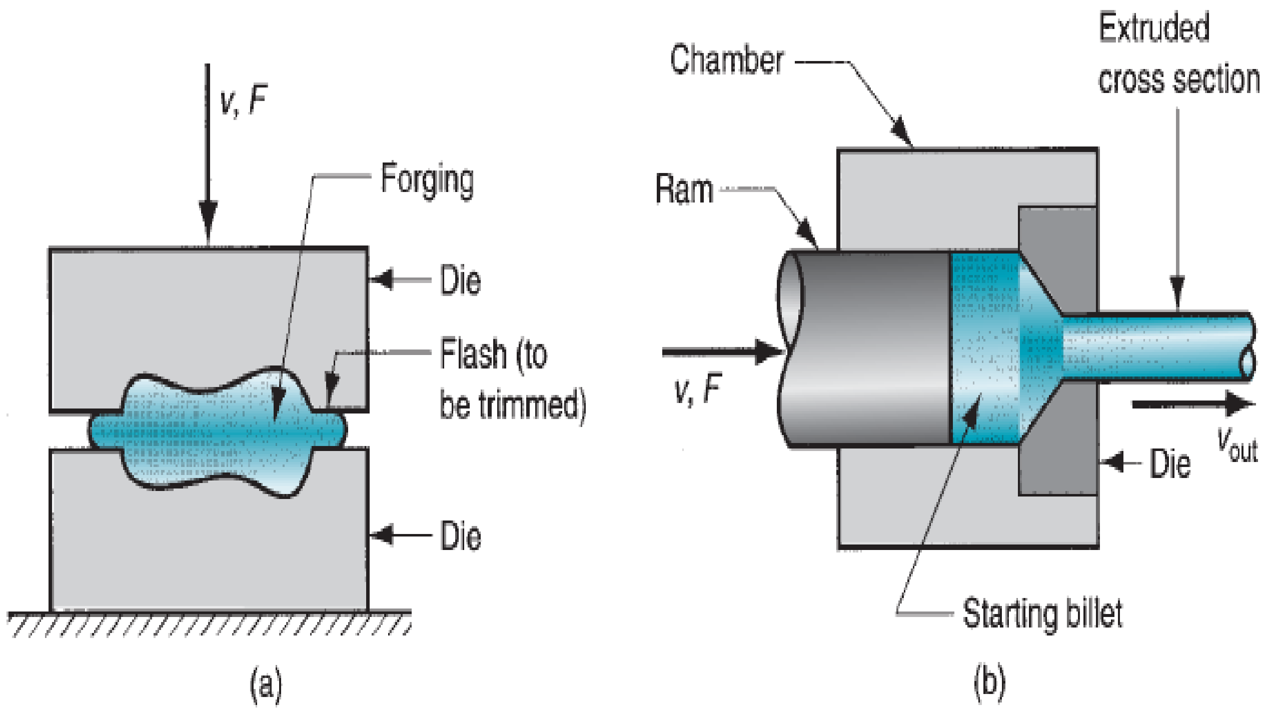

Figure (1-6) Deformation Processes; (a) forging, (b) extrusion

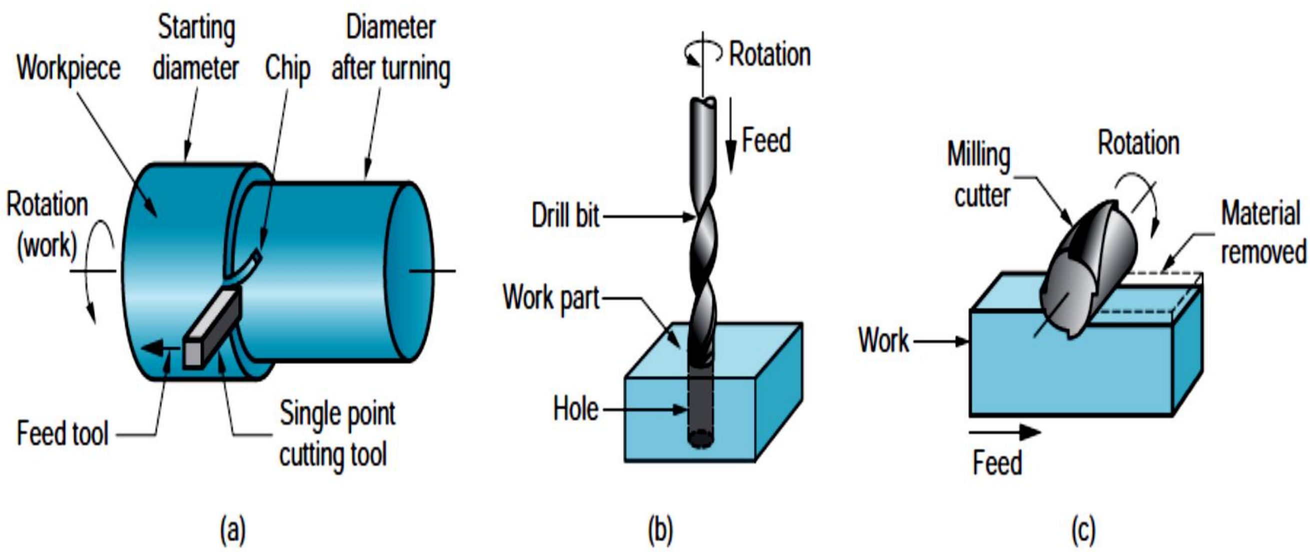

Figure (1-7) Machining Operations; (a) turning, (b) drilling, (c) milling

Net Shape Processes: transform nearly all of the material into product and require no subsequent machining to achieve final geometry**.**

Near Net Shape Processes: require minimum machining to produce the final shape.

Property-Enhancing Processes: it is performed to improve mechanical or physical properties of the work material. The most important property-enhancing processes involve heat treatments, which include various annealing and strengthening processes for metals and glasses. Sintering of powdered metals and ceramics is also a heat treatment that strengthens a pressed powder metal workpart.

Surface Processing Operations: are performed to clean, treat, coat, or deposit material onto the exterior surface of the work.

(a) Cleaning: includes both chemical and mechanical processes to remove dirt, oil, and other contaminants from the surface.

(b) Surface treatments: include mechanical working such as shot peening and sand blasting, and physical processes such as diffusion and ion implantation (**embedding atoms of one or more elements in a substrate using a high-energy beam of ionized particles**).

(c) Coating and thin film deposition processes: apply a coating of material to the exterior surface of the workpart. Common coating processes include electroplating **(it is electrolytic process in which metal ions in solution are deposited onto a cathode work material, the coating is grown by adhesion of ions of a second metal to the base metal surface.)**, anodizing of aluminum **(it is an electrolytic treatment that produces a stable oxide layer on a metallic surface, where the workpiece is anode, the surface coating is formed through chemical reaction of the substrate metal into an oxide layer)**, organic coating (call it painting), and porcelain enameling. Thin film deposition processes include physical vapor deposition (**family of deposition processes in which a material is converted to vapor phase and condensed onto a substrate surface as a thin film**) and chemical vapor deposition (**formation of a thin film on the surface of a substrate by chemical reactions or decomposition of gases)** to form extremely thin coatings of various substances.

(2) Assembly Operations

In which two or more separate parts are joined (permanently or semi-permanently) to form a new entity.

Permanent joining processes: include welding, brazing, soldering, and adhesive bonding.

Mechanical Fastening: it is used to fasten two (or more) parts together in a joint that can be conveniently disassembled. The **Threaded Fasteners** such as screws, bolts are used for nonpermanent joints.
Other mechanical assembly techniques form a more permanent connection; these include **rivets, press fitting (in which the two components have an interference fit between them.), and expansion fits (it is when only the internal part is cooled to contract it for assembly; once inserted into the mating component, it warms to room temperature, expanding to create the interference assembly.).**

Manufacturing Support Systems:

(1) Manufacturing engineering: it is responsible for planning the manufacturing processes-deciding what processes should be used to make the parts and assemble the products. This department is also involved in designing and ordering the machine tools and other equipment used by the operating departments to accomplish processing and assembly.
(2) Production planning and control: it is responsible for solving the logistics problem in manufacturing-ordering materials and purchased parts, scheduling production, and making sure that the operating departments have the necessary capacity to meet the production schedules.
(3) Quality control: it is responsible for designing and building products that conform to specifications and satisfy or exceed customer expectations.