Manufacturing Processes

Chapter One:
An Introduction

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What is Manufacturing??

- The word *manufacturing* is centuries old and derived from two Latin words *manus* (hand) and *factus* (make); the combination means by hand. Hence manufacturing literally means made by hand.

- Although modern manufacturing is accomplished by automated and computer-controlled machinery the word manufacturing is still in use.

Manufacturing Defined

- Manufacturing can be defined in two ways; technologically and economically.
- In technology, manufacturing is the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a starting material to make products. Manufacturing also includes assembly of multiple parts to make products.
- In economy, manufacturing is the transformation of materials into items of greater value by means of one or more processing and/or assembly operations.
- The key point is that manufacturing adds value to the material either by changing its shape or properties or by combining it with other materials that have been similarly altered.

Manufacturing Defined

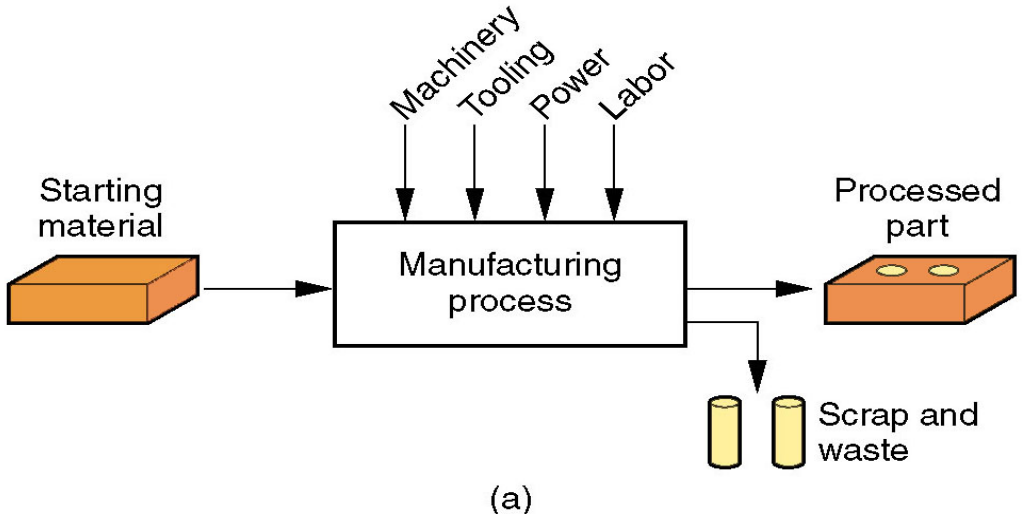

Figure 1.1 (a) Manufacturing as a technical process

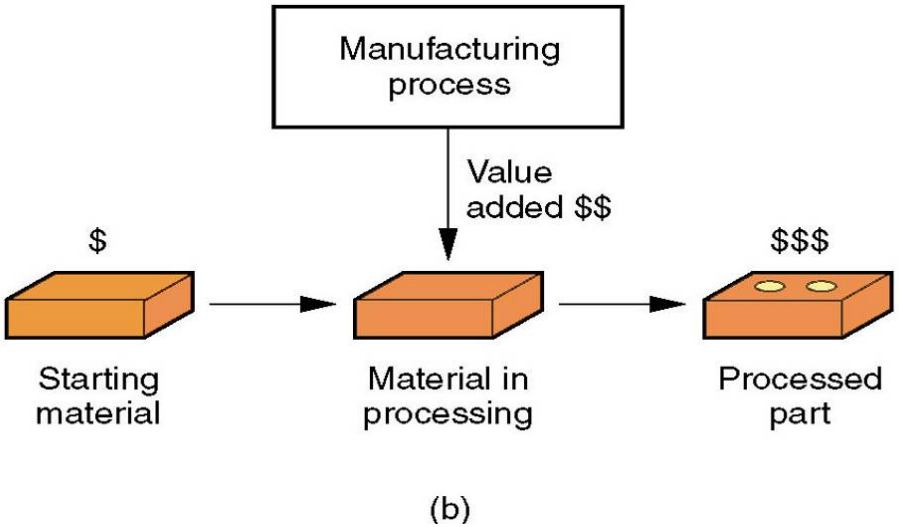

Figure 1.1 (b) Manufacturing as an economic process

Manufacturing Industries and Products

- Manufacturing is important to our lives. Yet, we do not manufacture stuff just for the sake of manufacturing. We manufacture because we want to make money!

- Industries in manufacturing is divided into three major categories; Primary, Secondary and Tertiary Industries.

1. Primary industries are those that cultivate and exploit natural resources, such as agriculture and mining.

2. Secondary industries are those that take the outputs of the primary industries and convert them into consumer and capital goods. (This type is of our concern because it is engaged directly in manufacturing).

3. Tertiary industries constitute the service sector of the economy.

Manufacturing Industries and Products

- Manufactured products: Final products by industries such as Aerospace, Automotive, Basic Metals, Computers, Electronics, Glass, Ceramics can be divided into two major classes:

1. Consumer goods: Products purchased directly by consumers, such as cars, PCs, TVs, etc.

2. Capital goods: Products purchased by other companies to produce goods and supply services, such as aircrafts, mainframe computers, railroad equipment, machine tools, construction equipment, etc.

Manufacturing Industries and Products

- Production Quantity (*Q*) and Product Variety (*V*).

1. The quantity of products made by a factory has a great influence on the way its people, facilities and procedures are organized. Annual production can be classified into 3 ranges:

- Low production: quantities in the range 1 to 100 units/year.
- Medium production: from 100 to 10,000 units/year.
- High production: 10,000 to millions of units/year. However and depending on the kinds of products, these ranges may shift by an order of magnitude or so.

2. The product variety: since some factories specialize in high production of only one product type while other factories produce a variety of products each type being made in low or medium quantities, it is instructive to identify product variety as a parameter distinct from production quality. It is logical to consider factories with a high number of product types to have high product variety.

Manufacturing Industries and Products

- There is an inverse correlation between production quantity and product variety. The higher the production quantity the lower the product variety and vise versa.

- Manufacturing plants tend to specialize in a combination of *Q* and *V* that lies somewhere inside the diagonal band in the figure.

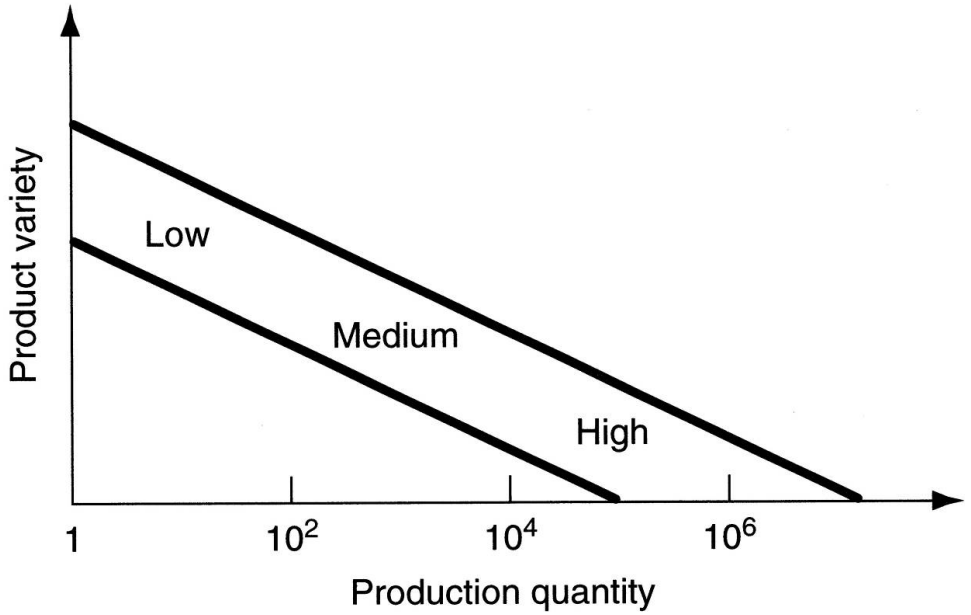

Figure 1.2 Relationship between *Q* and *V*.

Manufacturing Industries and Products

- Although *V* is a quantitative parameter, it is much less exact than *Q* because details on how much the designs differ is not captured simply by the number of different designs.

1. Soft product variety: small differences between products, e.g., between car models made on the same production line, with many common parts among models.

2. Hard product variety: products differ substantially; e.g. between a small car and a large truck, with few common parts.

Materials in Manufacturing

- Most engineering materials can be classified into one of the three basic categories: (1) Metals, (2) Ceramics and (3) Polymers.
- They have different chemistries and their mechanical and physical properties are dissimilar.
- These differences affect the manufacturing processes that can be used to produce products from them.
- In addition, there are (4) Composites: nonhomogenious mixtures of the other three basic types rather than a unique category.

Materials in Manufacturing

- The relationship of the four groups is pictured in the following figure.

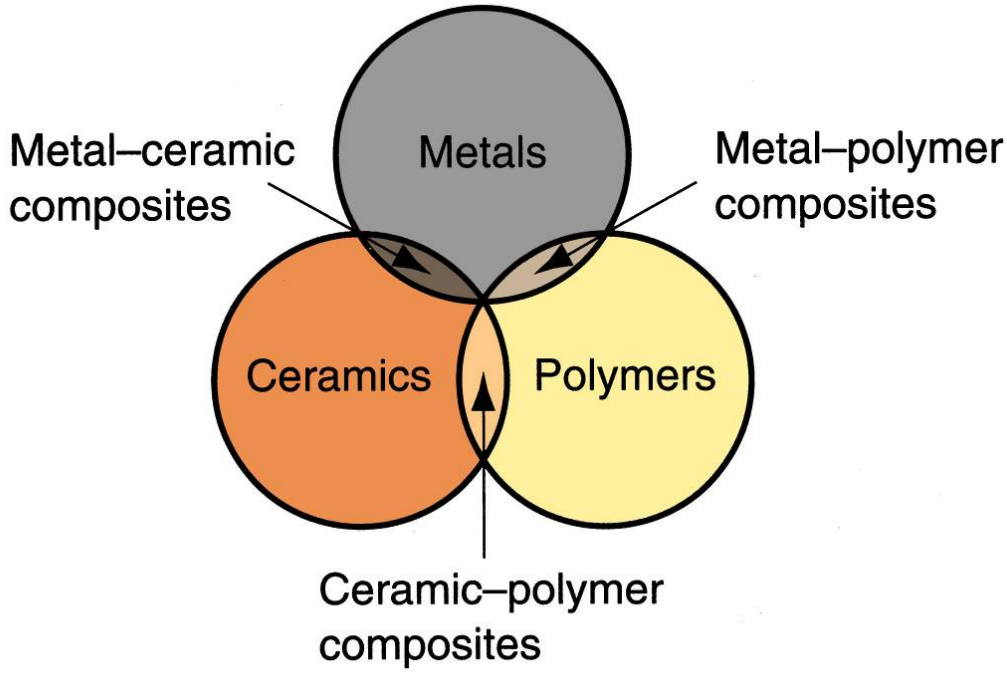

Figure 1.3 Venn diagram of three basic material types plus composites.

Materials in Manufacturing

[1] Metals: metals used in manufacturing are usually in the form of alloys (two ore more elements, at least one of which is metallic). Metals are divided into two basic groups; ferrous and nonferrous.

a. Ferrous metals: based on Iron (Fe) as the major alloying element. This group includes steel and cast iron.

- More than 75% of the metal tonnage throughout the world.

- Fe has limited commercial use, but when alloyed with carbon (C), Fe has more use and greater commercial value than any other metal.

- Fe when alloyed with C forms Steel or Cast Iron.

Materials in Manufacturing

- **Steel**: Is an Iron-Carbon alloy containing 0.02 to 2.11 wt. % C.
- Most important category within the ferrous metals group, due to low cost and good mechanical and physical properties.
- Its composition contains other metals such as Mg, Cr, Ni, Mo, etc, to enhance the properties of the alloy.
- Used widely in construction, transportation and consumer products.

Materials in Manufacturing

- **Cast iron**: Iron-Carbon alloy containing ~2 to ~4 wt.% C.
- Used primarily in sand casting.
- Other elements such as Si (0.5 to 3 wt.%) is present in the alloy. Other elements are often added as well.
- Gray cast iron is the most common type of cast iron; its applications include blocks and heads for internal combustion engines, manholes covers, etc.

Materials in Manufacturing

b. Nonferrous metals: These include other metallic elements and their alloys.

- In almost all cases, the alloys are more important commercially than the pure metals.

- Some examples are Gold alloys, Titanium alloys, Copper alloys, etc.

Materials in Manufacturing

[2] Ceramics: A compound containing metallic (or semimetallic) and nonmetallic (O, N and C) elements.

- Traditional ceramics: Been used for thousands of years. They include: clay (consists of fine particles of hydrous aluminum silicate and other minerals used in making brick, tile and pottery); silica (the basis of nearly all glass products); and alumina and silicon carbide (abrasive materials used in grinding).

- Modern ceramics: Consists of alumina of enhanced properties. Newer ceramics include carbides, metal carbides such as tungsten and titanium carbides (used as cutting tool materials); and nitrides (e.g. titanium nitride and boron nitride, used as cutting tools and grinding abrasives).

- For processing purposes, ceramics can be divided into (1) crystalline ceramics and (2) amorphous ceramics (glasses). The former are formed in various ways from powders and then sintered, while the later can be melted and cast and then formed (e.g. glass blowing).

Materials in Manufacturing

[3] Polymers: A compound formed of repeating structural units called *mers*, whose atoms share electrons to form very large molecules. They consist of carbon plus one or more other elements such as hydrogen, oxygen, nitrogen and chlorine. They are divided into three categories:

- Thermoplastic polymers: can be subjected to multiple heating and cooling cycles without altering molecular structure; e.g. polyethylene, polystyrene, polyvinylchloride and nylon.

- Thermosetting polymers: molecules chemically transform (cure) into a rigid structure upon cooling from a heated plastic condition; e.g. epoxies and amino resins.

- Elastomers: they exhibit significant elastic behavior; e.g. silicon and rubber.

Materials in Manufacturing

[4] Composites: A mixtures of the other three basic types. A composite is a material consisting of two or more phases that are processed separately and then bonded together to achieve properties superior to its constituents.

- Phase: Homogeneous mass of material, such as grains of identical unit cell structure in a solid metal.
- The usual structure of a composite material consists of particles or fibers of one phase mixed in a second phase, called the matrix.
- Composites are found in nature (wood) and they can be produced synthetically (fiber-reinforced plastic).
- Properties depend on its components, physical shapes of components, and the way they are combined to form the final material. Some composites combine high strength and light weight and are used as aircraft components, car bodies, etc. Other composites are strong and hard, and capable of maintaining these properties at high temperatures; e.g. cemented carbide cutting tools.

Manufacturing Processes

- Manufacturing processes can be divided into two basic types:

1. Processing operations: transforms a work material from one state of completion to a more advanced state closer to the final desired product. It adds value by changing geometry, properties or appearance of the starting material.

2. Assembly operations: joins two or more components in order to create a new entity called an assembly, subassembly, etc.

Manufacturing Processes

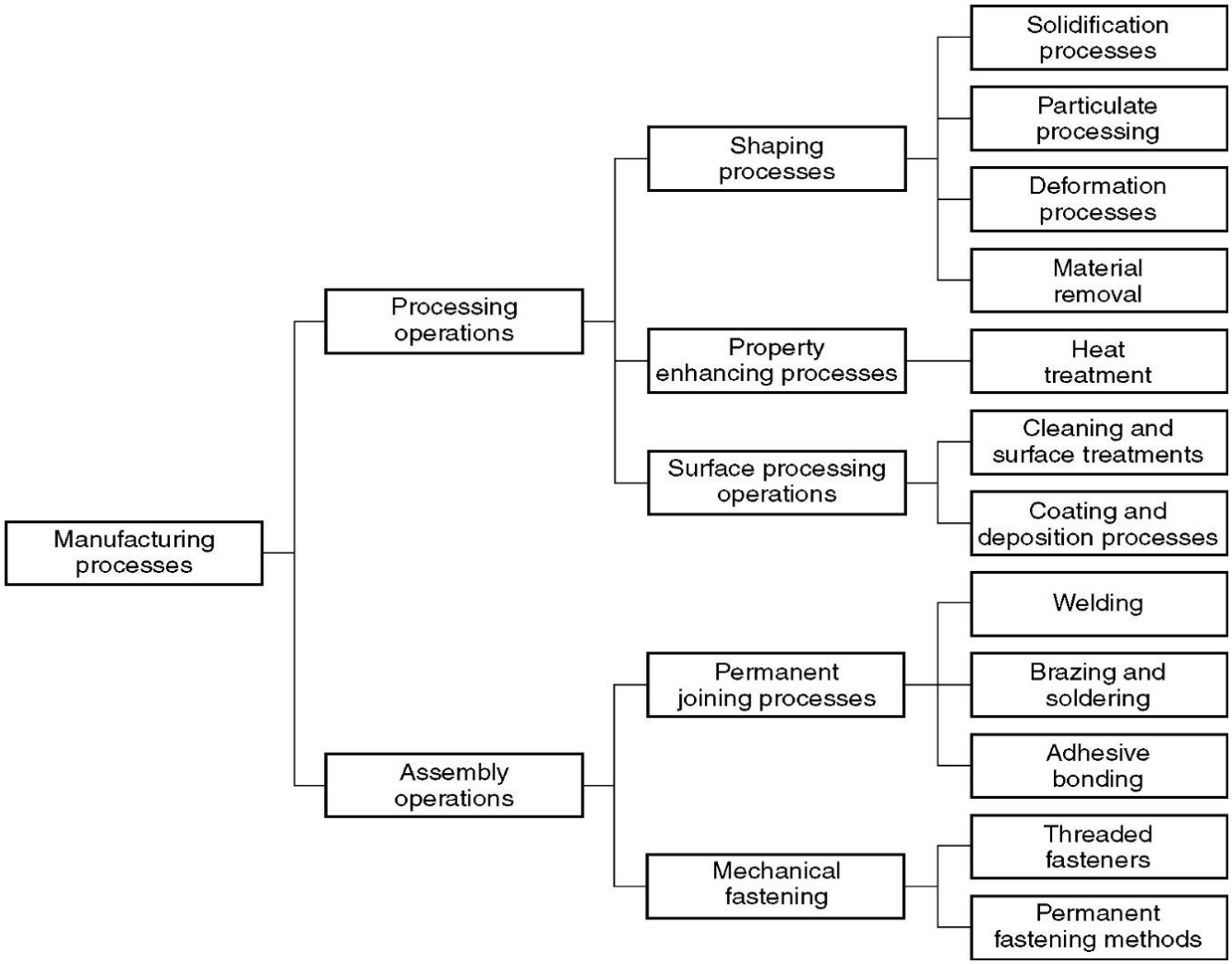

Figure 1.4 Classification of manufacturing processes

Manufacturing Processes

- Processing operations: use energy to alter a workpart's shape, physical properties or appearance in order to add value to the material. There are three categories of processing operations:

1. Shaping operations: alter the geometry of the work material by methods including casting, forging and machining.

2. Property-enhancing operations: add value to the material by improving its physical properties without changing its shape; e.g. Heat treatment.

3. Surface processing operations: performed to clean, treat, coat or deposit material onto the exterior surface of the work. Examples for coating are plating and painting.

Manufacturing Processes

- Shaping processes: change the geometry of a work material by application of heat or mechanical force or a combination of both. It can be classified into four categories:

1. Solidification processes: the starting material is a heated liquid or semifluid that cools or solidifies to form the part geometry.

2. Particulate processing: the starting material is a powder, and the powders are formed and heated into the desired geometry.

3. Deformation processes: the starting material is a ductile solid that is deformed to shape the part.

4. Material removal processes: the starting material is a solid, from which material is removed so that the resulting part has the desired geometry.

Manufacturing Processes

- Solidification process: starting material is heated sufficiently to transform it to the liquid state. With the material (metals, plastics and ceramic glasses) in the liquid state, it can be poured into a mold cavity and allowed to solidify , thus taking a solid shape that is the same as the cavity.

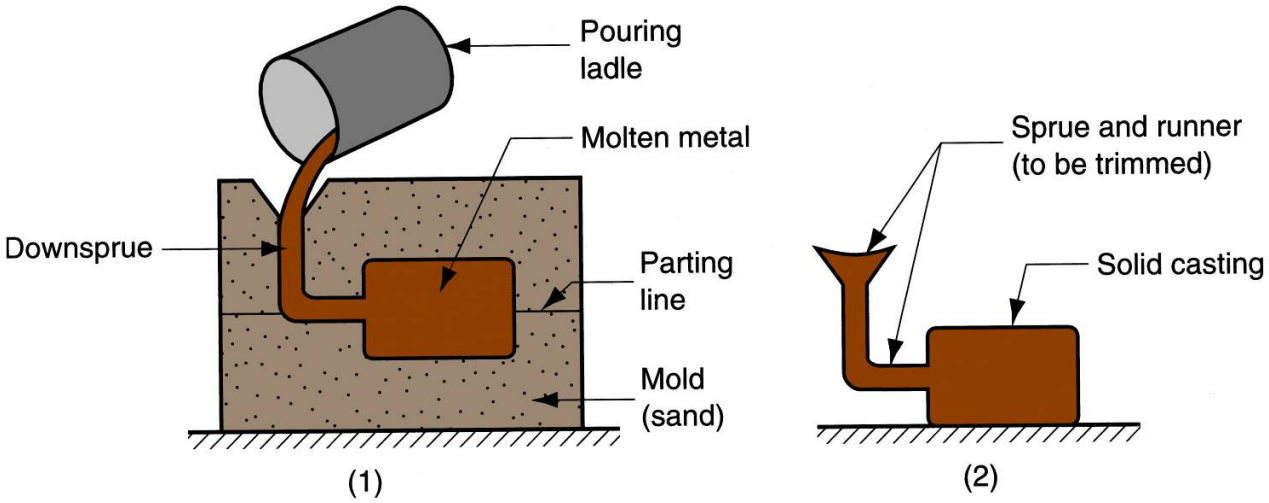

Figure 1.5 Casting (metals) and molding (plastics) processes.

Manufacturing Processes

- Particulate processing: Starting materials are powders of metals or ceramics. The powders are then pressed and sintered. The powders are first squeezed into a die cavity under a high pressure and then heated to bond the individual particles together.

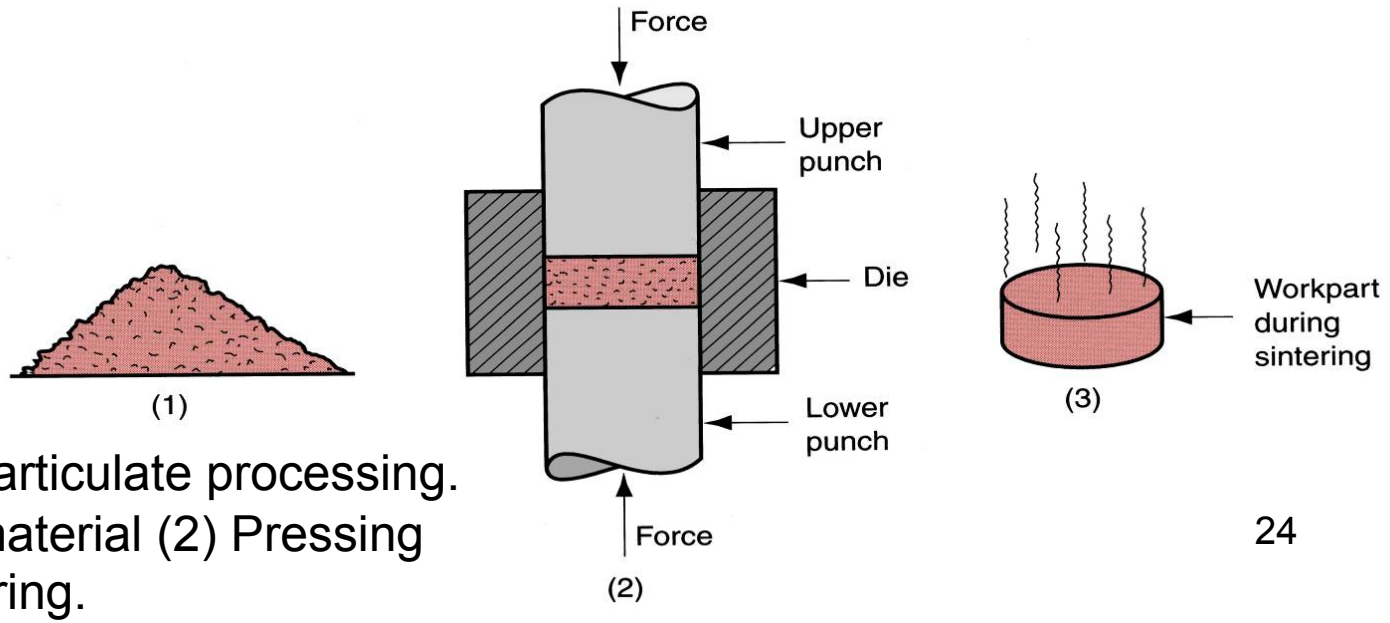

Figure 1.6 Particulate processing. (1) Starting material (2) Pressing and (3) Sintering.

Manufacturing Processes

- Deformation processes: the starting workpart is shaped by application of forces that exceed the yield strength of the material (material must be ductile enough (accomplished by means of heating)), this process includes extrusion and forging.

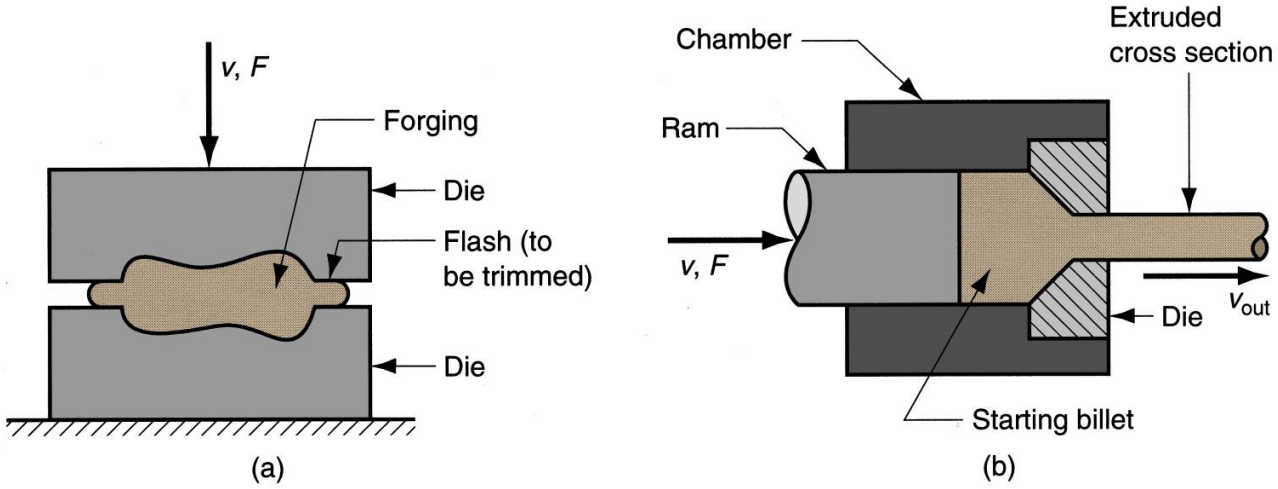

Figure 1.7 Deformation processes (a) forging (b) extrusion

Manufacturing Processes

- Material removal processes: operations that remove excess material from the starting workpart to get the desired geometry. Most common processes in this category include machining and grinding. The former includes turning, drilling and milling. Other special processes are known as nontraditional processes as they use lasers, electron beams, electric discharge, etc.

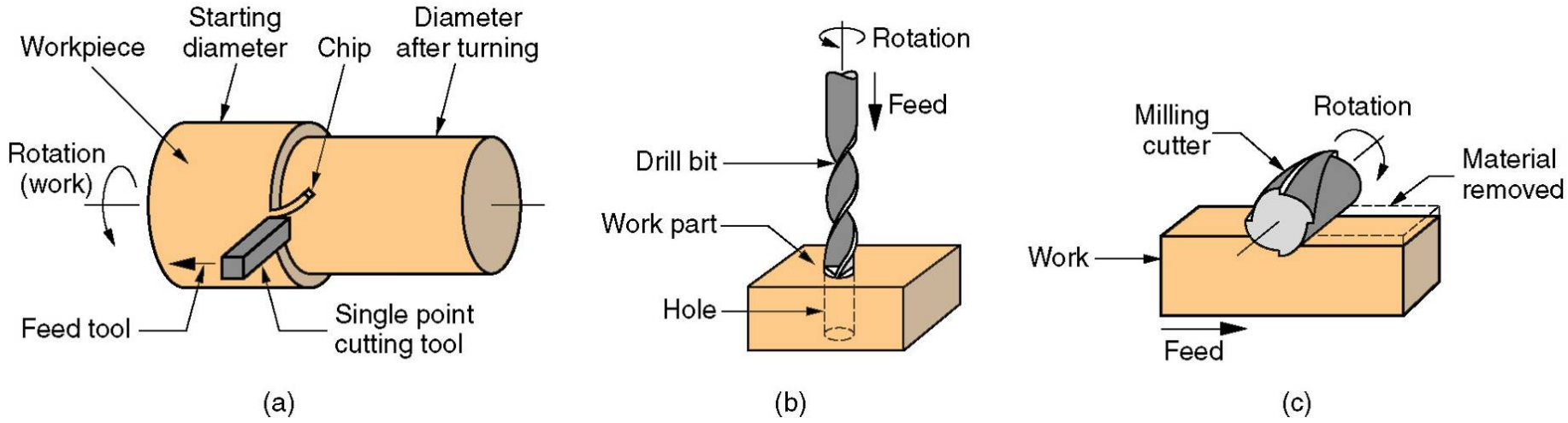

Figure 1.8 Material removal processes. (a) turning (b) drilling and (c) milling.

Manufacturing Processes

- Waste: it is desirable to minimize the waste and scrap in converting a starting workpart into a desired geometry.

- Material removal processes tend to be wasteful of material, simply by the way they work.

- Solidification processes convert close to 100% of the starting material into final product, such processes are called net shape processes, while other processes that require minimum machining to produce the final shape are called near net shape processes.