

# INTRODUCTION

- What is Manufacturing?
- Materials in Manufacturing
- Manufacturing Processes
- Production Systems
- Organization of the Book

# Manufacturing is Important!

- Technologically
- Economically
- Historically

# Manufacturing Is Important Technologically

Technology can be defined as the application of science to provide society and its members with those things that are needed or desired

- Technology provides products that help our society and its members live better
- What do these products have in common? They are all manufactured
- Manufacturing is the essential factor that makes technology possible

# Manufacturing Is Important Economically

Manufacturing is a means by which a nation creates material wealth

- In the U.S. manufacturing constitutes ~ 20% of GNP
- Government is as much of GNP as manufacturing, but it creates no wealth

## U.S. economy:

Sector	% of GNP
Manufacturing	20%
Agriculture, minerals, etc.	5%
Construction & utilities	5%
Service – retail, transportation, banking, communication, education, and government	70%

# Manufacturing is Important Historically

Historically, the importance of manufacturing in the development of civilization is usually underestimated

- Throughout history, human cultures that were better at making things were more successful
- Making better tools meant better crafts & weapons
  - Better crafts allowed the people to live better
  - Better weapons allowed them to conquer other cultures in times of conflict
- To a significant degree, the history of civilization is the history of humans' ability to make things

# What is Manufacturing?

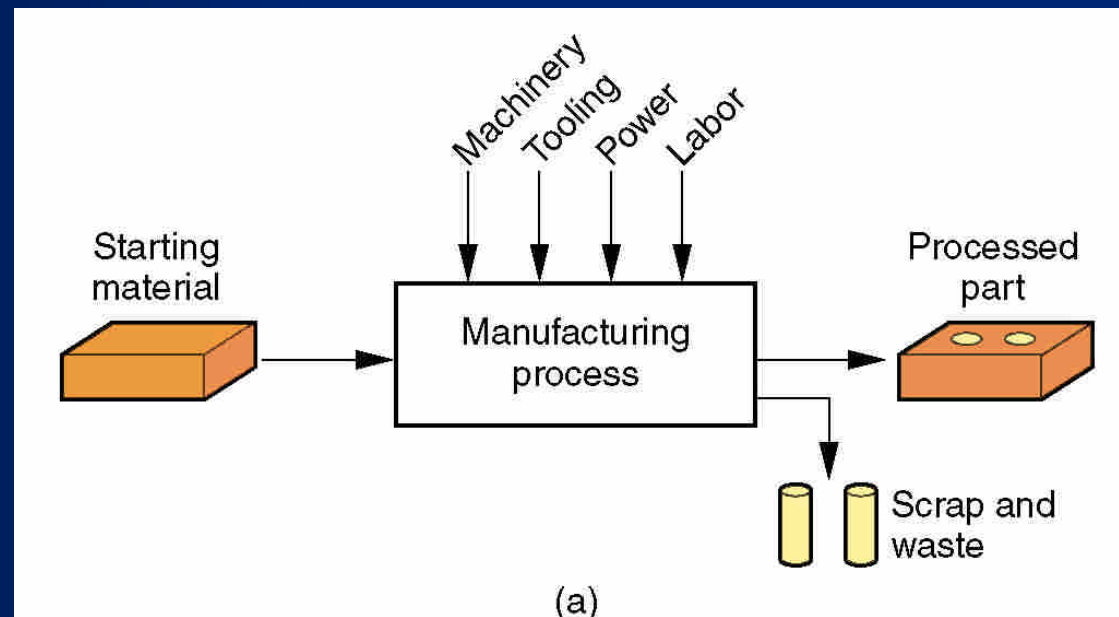
*Manufacture* is derived from two Latin words *manus* (hand) and *factus* (make); the combination means “made by hand”

- “Made by hand” accurately described the manual methods used when the English word “manufacture” was first coined around 1567 A.D.
- Most modern manufacturing is accomplished by automated and computer-controlled machinery that is manually supervised

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

- Manufacturing is almost always carried out as a sequence of operations

Figure 1.1 (a)  
Manufacturing  
as a technical  
process



*Manufacturing* is the transformation of materials into items of greater value by means of one or more processing and/or assembly operations

- Manufacturing *adds value* to the material by changing its shape or properties, or by combining it with other materials that have been similarly altered

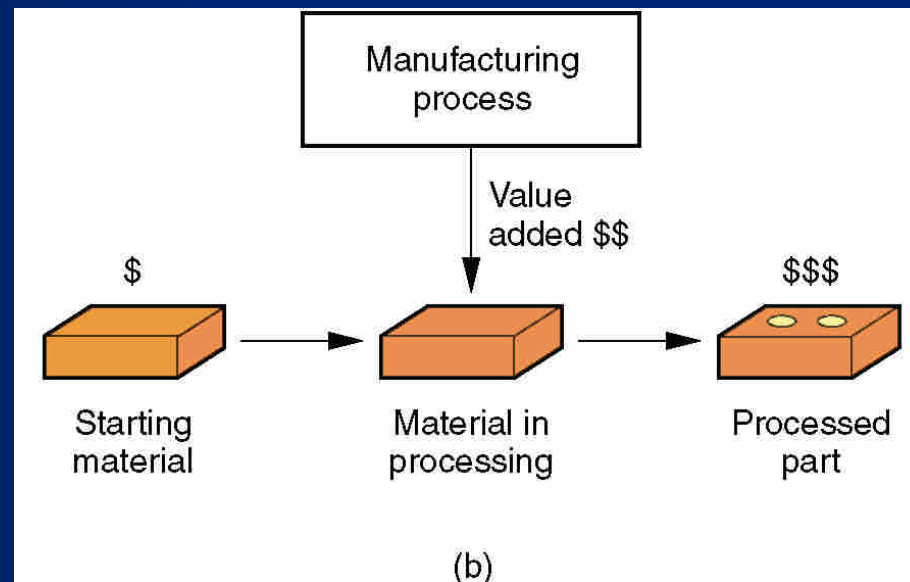


Figure 1.1 (b)  
Manufacturing  
as an economic  
process



# Manufacturing Industries

Industry consists of enterprises and organizations that produce or supply goods and services

- Industries can be classified as:
  1. Primary industries - those that cultivate and exploit natural resources, e.g., agriculture, mining
  2. Secondary industries - take the outputs of primary industries and convert them into consumer and capital goods - manufacturing is the principal activity
  3. Tertiary industries -service sector of the economy

## Manufacturing Industries - continued

- Most secondary industries are companies that do manufacturing; others are construction and power generation
- However, manufacturing includes several industries whose production technologies are not covered in this course; e.g., apparel, beverages, chemicals, and food processing
- For our purposes, manufacturing means production of *hardware*, which ranges from nuts and bolts to digital computers and military weapons, as well as plastic and ceramic products

# Production Quantity

The quantity of products  $Q$  made by a factory has an important influence on the way its people, facilities, and procedures are organized

Annual production quantities can be classified into three ranges:

<u>Production range</u>	<u>Annual Quantity <math>Q</math></u>
Low production	1 to 100 units
Medium production	100 to 10,000 units
High production	10,000 to millions of units

# Product Variety

Product variety  $P$  refers to different product types produced in the plant

- Product variety is distinct from production quantity
- Different products have different shapes and sizes; they are intended for different markets; some have more parts than others
- The number of different product types made each year in a factory can be counted
- When the number of product types made in the factory is high, this indicates high product variety

- An inverse correlation exists between product variety  $P$  and production quantity  $Q$  in factory operations
- If a factory's  $P$  is high, then  $Q$  is likely to be low; and if  $Q$  is high, then  $P$  is likely to be low

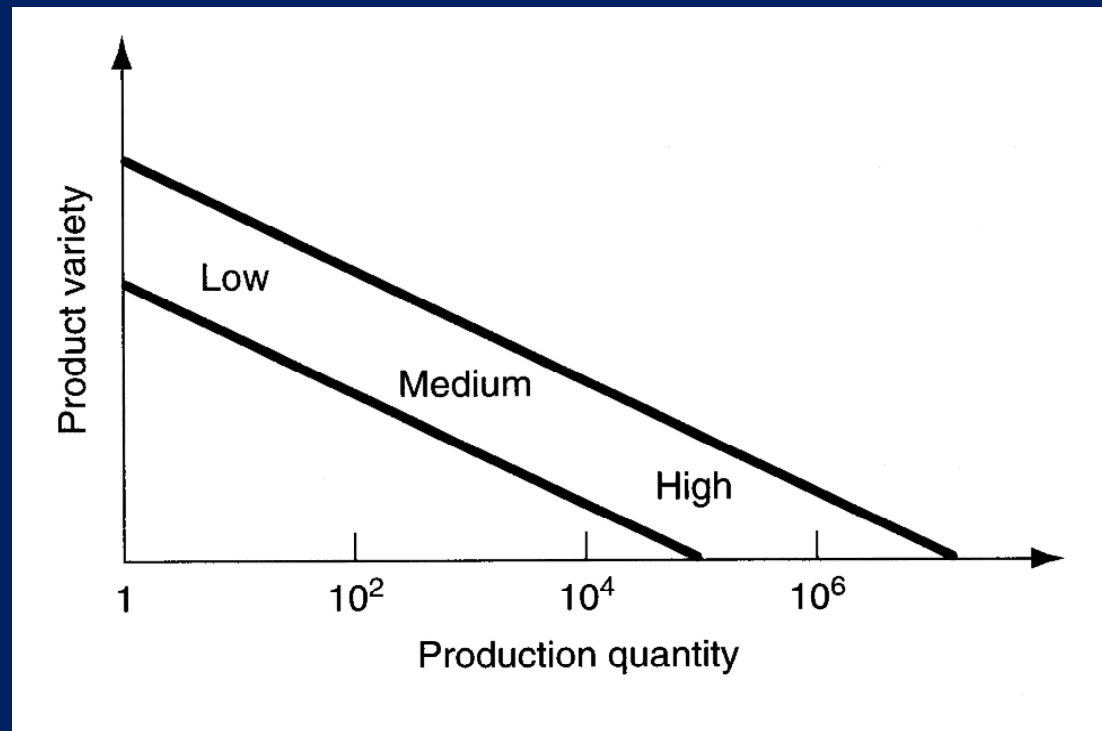


Figure 1.2 -  
P-Q Relationship

# Production Quantity and Product Variety

Although  $P$  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

- *Soft product variety* - small differences between products, e.g., differences between car models made on the same production line, in which there is a high proportion of common parts among models
- *Hard product variety* - products differ substantially, and there are few, if any, common parts, e.g., the difference between a small car and a large truck

# Manufacturing Capability

A manufacturing plant consists of a set of *processes* and *systems* (and people, of course) designed to transform a certain limited range of *materials* into products of increased value

- The three building blocks - materials, processes, and systems - are the subject of modern manufacturing
- Manufacturing capability includes:
  - Technological processing capability
  - Physical product limitations
  - Production capacity

# Technological Processing Capability

The available set of manufacturing processes in the plant (or company)

- Certain manufacturing processes are suited to certain materials
  - By specializing in certain processes, the plant is also specializing in certain material types
- Includes not only the physical processes, but also the expertise of the plant personnel



# Physical Product Limitations

Given a plant with a certain set of processes, there are size and weight limitations on the parts or products that can be made in the plant

- Product size and weight affect:
  - Production equipment
  - Material handling equipment
- The production and material handling equipment, and plant size must be planned for products that lie within a certain size and weight range

# Production Capacity

The production quantity that can be produced in a given time period (e.g., month or year)

- Commonly called *plant capacity*, or *production capacity*, it is defined as the maximum rate of production that a plant can achieve under assumed operating conditions
  - Operating conditions refer to number of shifts per week, hours per shift, direct labor manning levels in the plant, and so on
- Usually measured in terms of output units, such as tons of steel or number of cars produced by the plant

# Materials in Manufacturing

- Most engineering materials can be classified into one of three basic categories:
  1. Metals
  2. Ceramics
  3. Polymers
- Their chemistries are different, their mechanical and physical properties are dissimilar, and these differences affect the manufacturing processes that can be used to produce products from them

- In addition to the three basic categories, there are:
  4. Composites - nonhomogeneous mixtures of the other three basic types rather than a unique category

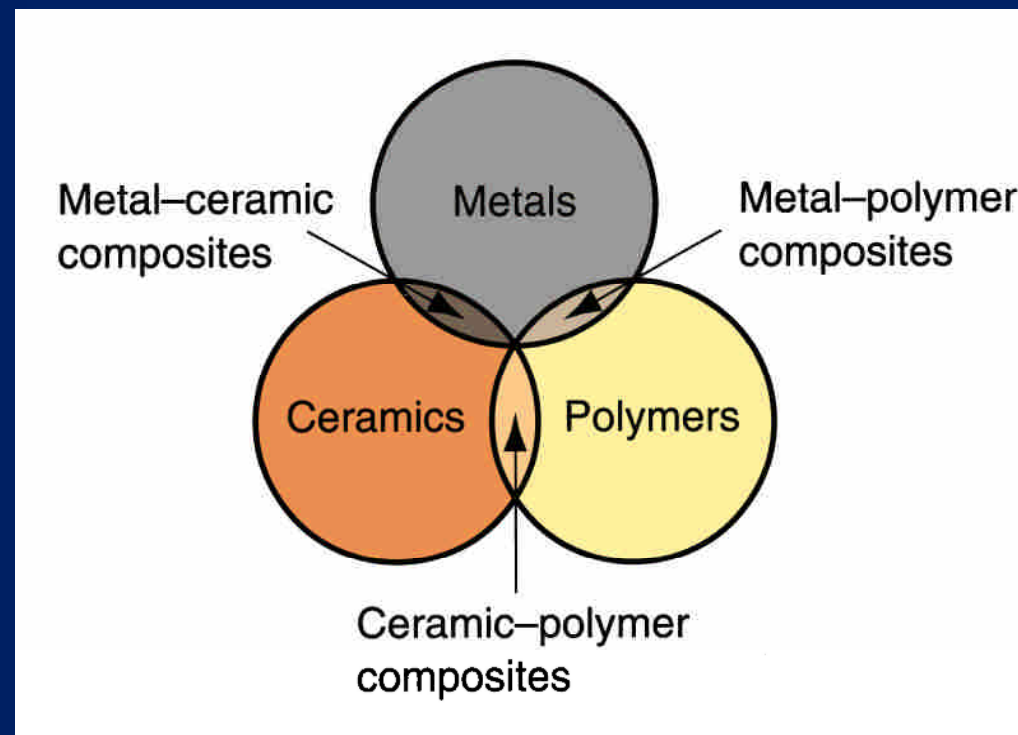


Figure 1.3 –  
Venn diagram  
of three basic  
Material types  
plus composites

# Metals

Usually *alloys*, which are composed of two or more elements, at least one of which is metallic

- Two basic groups:
  1. Ferrous metals - based on iron, comprise ~ 75% of metal tonnage in the world:
    - Steel = iron-carbon alloy with 0.02 to 2.11% C
    - Cast iron = alloy with 2% to 4% C
  2. Nonferrous metals - all other metallic elements and their alloys: aluminum, copper, gold, magnesium, nickel, silver, tin, titanium, etc.

# Ceramics

A compound containing metallic (or semi-metallic) and nonmetallic elements. Typical nonmetallic elements are oxygen, nitrogen, and carbon

- For processing purposes, ceramics divide into:
  1. Crystalline ceramics – includes:
    - Traditional ceramics, such as clay (hydrous aluminum silicates)
    - Modern ceramics, such as alumina ( $\text{Al}_2\text{O}_3$ )
  2. Glasses – mostly based on silica ( $\text{SiO}_2$ )

# Polymers

A compound formed of repeating structural units called *mers*, whose atoms share electrons to form very large molecules

- Three categories:
  1. *Thermoplastic polymers* - can be subjected to multiple heating and cooling cycles without altering their molecular structure
  2. *Thermosetting polymers* - molecules chemically transform (cure) into a rigid structure upon cooling from a heated plastic condition
  3. *Elastomers* - exhibit significant elastic behavior

# Composites

A material consisting of two or more phases that are processed separately and then bonded together to achieve properties superior to its constituents

- A *phase* = a homogeneous mass of material, such as grains of identical unit cell structure in a solid metal
- Usual structure consists of particles or fibers of one phase mixed in a second phase
- Properties depend on components, physical shapes of components, and the way they are combined to form the final material



# Manufacturing Processes

Two basic types:

1. Processing operations - transform a work material from one state of completion to a more advanced state
  - Operations that change the geometry, properties, or appearance of the starting material
2. Assembly operations - join two or more components in order to create a new entity

# Processing Operations

Alters a workpart's shape, physical properties, or appearance in order to add value to the material

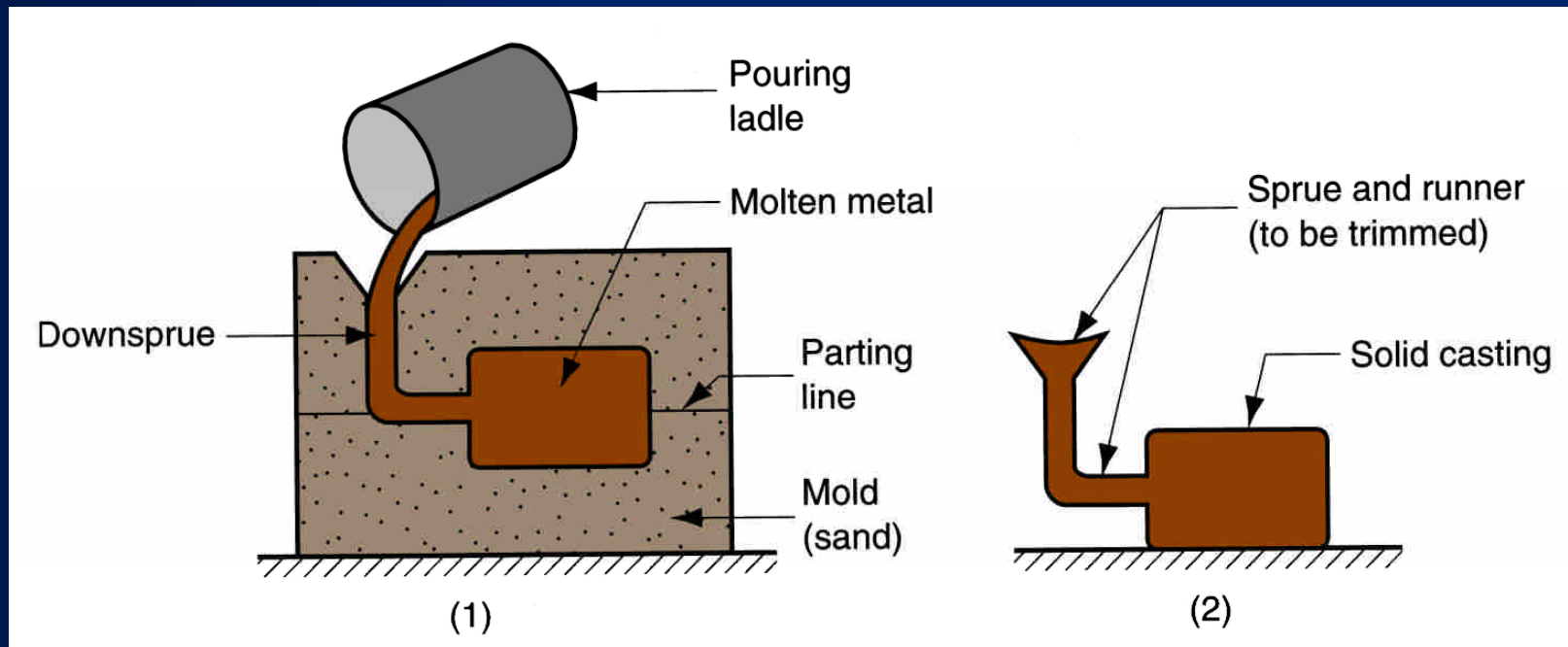
- Three categories of processing operations:
  1. Shaping operations - alter the geometry of the starting work material
  2. Property-enhancing operations - improve physical properties of the material without changing its shape
  3. Surface processing operations - performed to clean, treat, coat, or deposit material onto the exterior surface of the work

# Shaping Processes – Four Categories

1. *Solidification processes* - starting material is a heated *liquid* or *semifluid* that solidifies to form part geometry
2. *Particulate processing* - starting material is a *powder*, and the powders are formed into desired geometry and then sintered to harden
3. *Deformation processes* - starting material is a *ductile solid* (commonly metal) that is deformed
4. *Material removal processes* - starting material is a *solid* (ductile or brittle), from which material is removed so resulting part has desired geometry

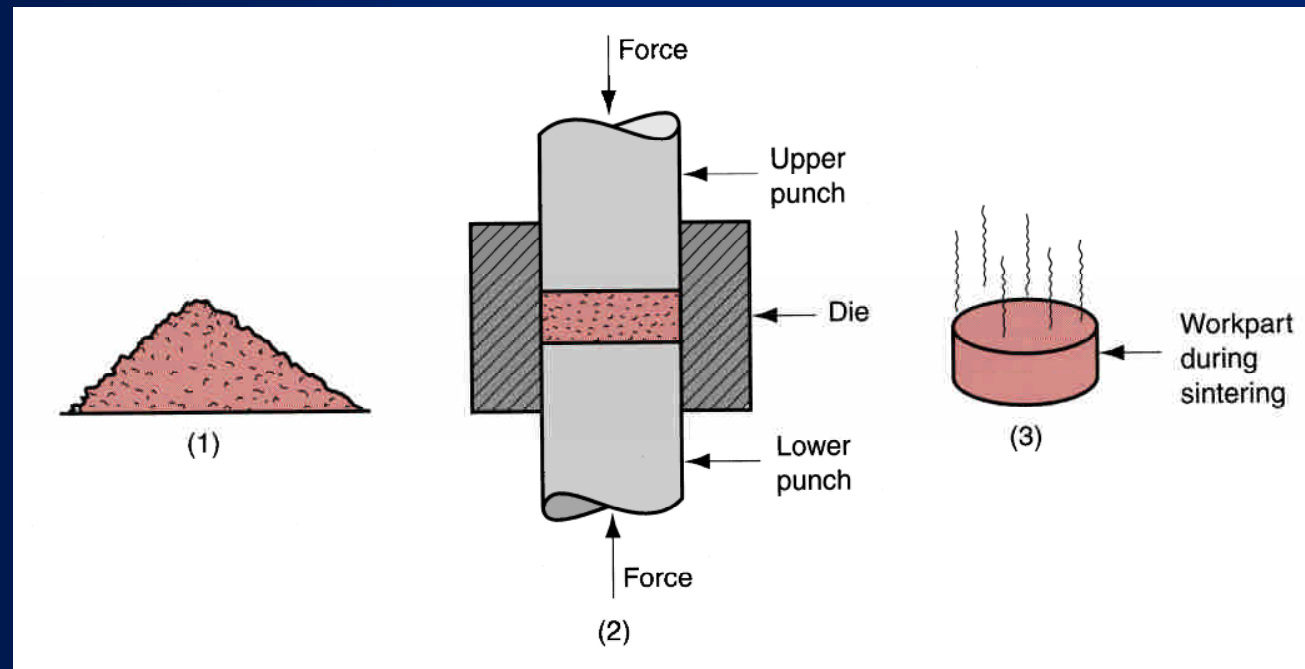
# Solidification Processes

- Starting material is heated sufficiently to transform it into a liquid or highly plastic state
- Examples: Casting for metals, molding for plastics



# Particulate Processing

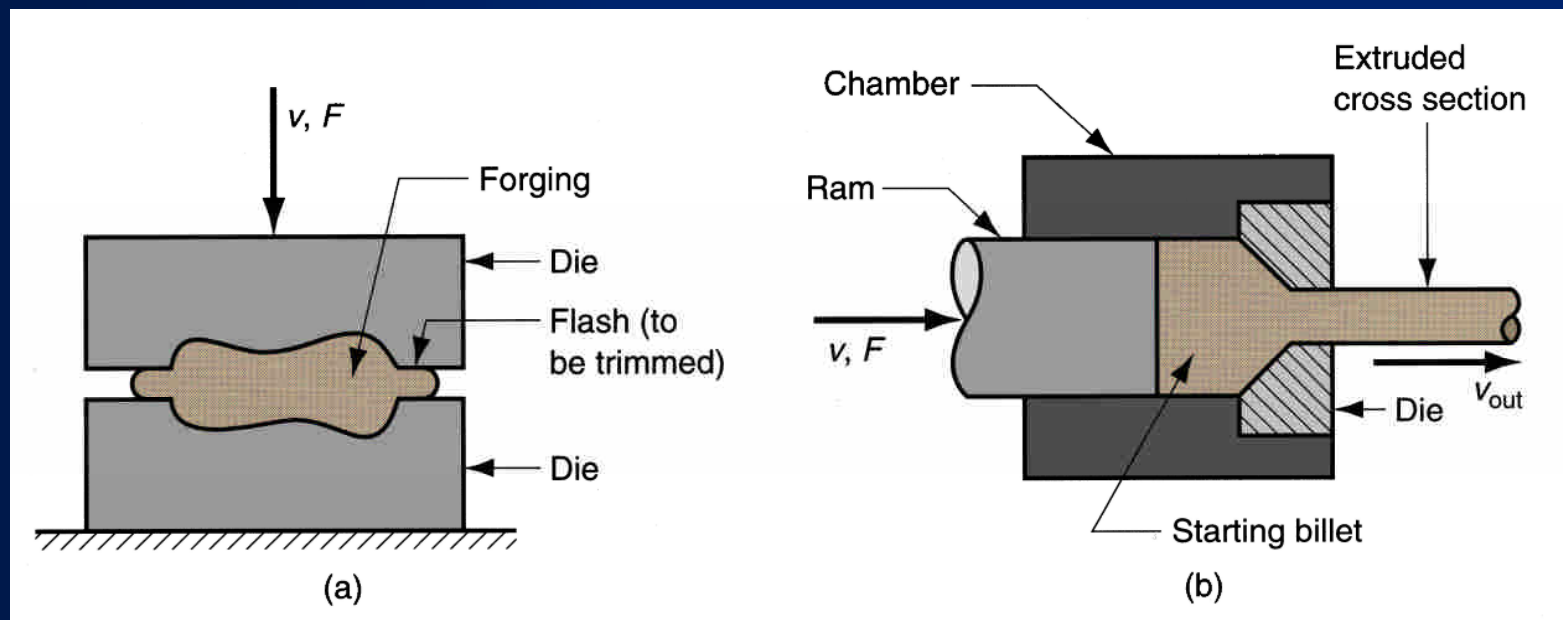
- Starting materials are powders of metals or ceramics
- Usually involves pressing and sintering, in which powders are first squeezed in a die cavity and then heated to bond the individual particles



# Deformation Processes

Starting workpart is shaped by application of forces that exceed the yield strength of the material

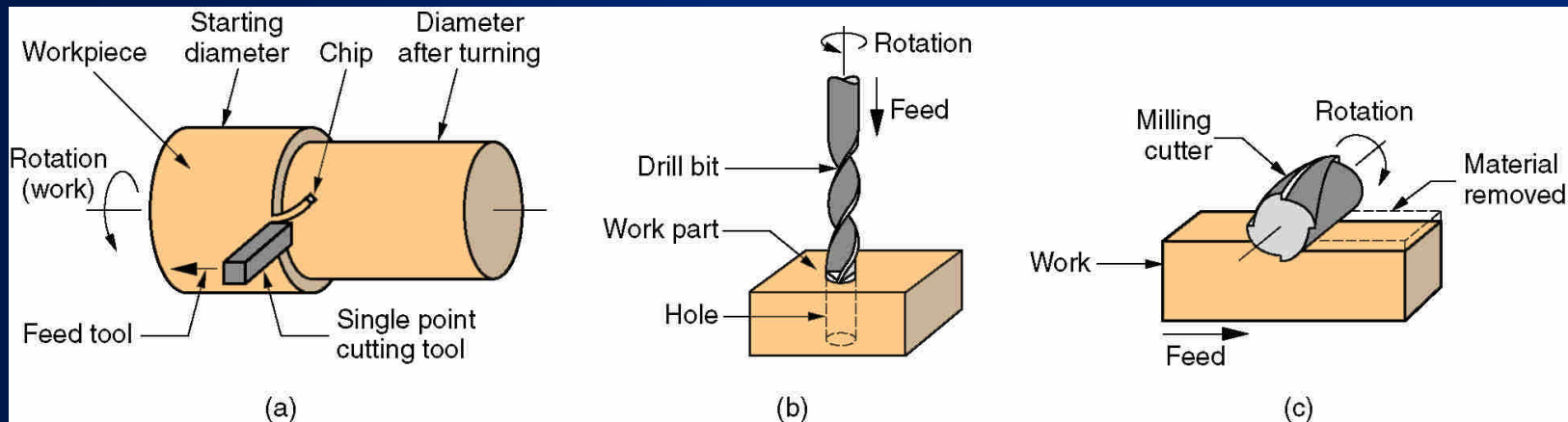
- Examples: (a) forging, (b) extrusion



# Material Removal Processes

Excess material removed from the starting workpiece so what remains is the desired geometry

- Examples: machining such as turning, drilling, and milling; also grinding and nontraditional processes



# Waste in Shaping Processes

It is desirable to minimize waste and scrap in part shaping

- Material removal processes tend to be wasteful in the unit operation, simply by the way they work
- Casting and molding usually waste little material
- Terminology:
  - *Net shape processes* - when most of the starting material is used and no subsequent machining is required to achieve final part geometry
  - *Near net shape processes* - when minimum amount of machining is required



# Property-Enhancing Processes

- Performed to improve mechanical or physical properties of the work material
- Part shape is not altered, except unintentionally
- Examples:
  - Heat treatment of metals and glasses
  - Sintering of powdered metals and ceramics

# Surface Processing Operations

1. Cleaning - chemical and mechanical processes to remove dirt, oil, and other contaminants from the surface
  2. Surface treatments - mechanical working such as sand blasting, and physical processes like diffusion
  3. Coating and thin film deposition - coating exterior surface of the workpart
- Several surface processing operations used to fabricate integrated circuits

# Assembly Operations

Two or more separate parts are joined to form a new entity

- Types of assembly operations:
  1. Joining processes – create a permanent joint.
    - Examples: welding, brazing, soldering, and adhesive bonding
  2. Mechanical assembly – fastening by mechanical methods
    - Examples: use of screws, bolts, nuts, other threaded fasteners; press fitting, expansion fits

# Production Systems

The people, equipment, and procedures designed for the combination of materials and processes that constitute a firm's manufacturing operations

- A manufacturing firm must have systems to efficiently accomplish its type of production
- Two categories of production systems:
  1. Production facilities
  2. Manufacturing support systems
- Both categories include people (people make these systems work)

# Production Facilities

The factory, production equipment, and material handling equipment

- The facilities "touch" the product
- Also includes the way the equipment is arranged in the factory - the *plant layout*
- Equipment usually organized into logical groupings, called *manufacturing systems*
  - Examples: automated production line, machine cell consisting of an industrial robot and two machine tools

# Production Facilities and Product Quantities

- A company designs its manufacturing systems and organizes its factories to serve the particular mission of each plant
- Certain types of production facilities are recognized as the most appropriate for a given type of manufacturing (combination of product variety and production quantity)
- Different facilities are required for each of the three quantity ranges

# Low Quantity Production

*Job shop* is the term used for this production facility

- Low quantity range = 1 to 100 units/year
- A job shop makes low quantities of specialized and customized products
- Products are typically complex, e.g., space capsules, prototype aircraft, special machinery
- Equipment in a job shop is general purpose
- Labor force is highly skilled
- Designed for maximum flexibility

## Medium Quantity Production

- Medium quantity range = 100 to 10,000 units annually
- Two different types of facility, depending on product variety:
  - Hard product variety: *batch production*
  - Soft product variety: *cellular manufacturing*



# High Production

- High quantity range = 10,000 to millions of units per year
- Referred to as *mass production*
  - High demand for product
  - Manufacturing system dedicated to the production of that product
- Two categories of mass production:
  1. Quantity production
  2. Flow line production

# Quantity Production

Mass production of single parts on single machine or small numbers of machines

- Typically involves standard machines equipped with special tooling
- Equipment is dedicated full-time to the production of one part type
- Typical layouts used in quantity production = process layout and cellular layout

# Flow Line Production

Multiple machines or workstations arranged in sequence, e.g., production lines

- Product is complex and requires multiple processing and/or assembly operations
- Work units are physically moved through the sequence to complete the product
- Workstations and equipment are designed specifically for the product to maximize efficiency

# Manufacturing Support Systems

- A company must organize itself to design the processes and equipment, plan and control the production orders, and satisfy product quality requirements
- These functions are accomplished by manufacturing support systems - people and procedures by which a company manages its production operations
- Typical departments:
  1. Manufacturing engineering
  2. Production planning and control
  3. Quality control

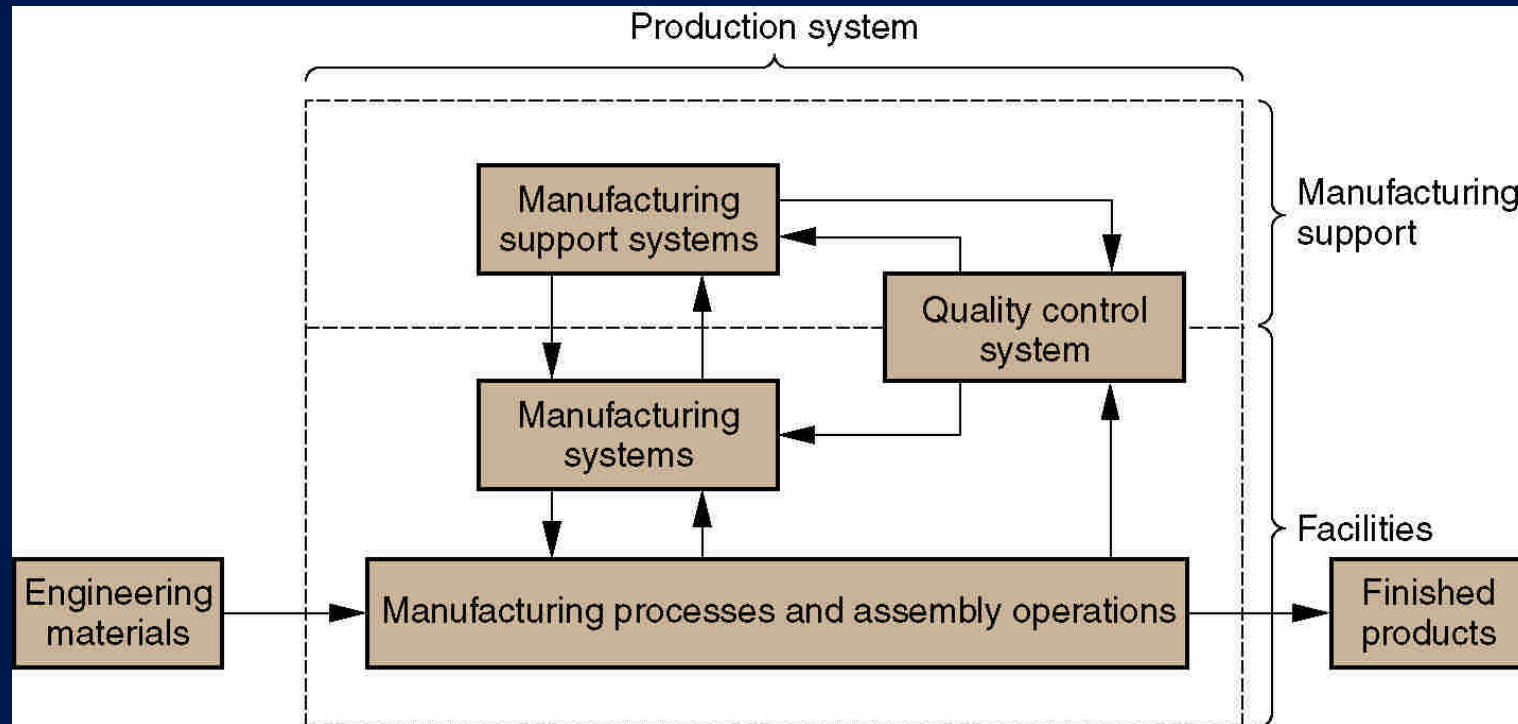


Figure 1.10 – Overview of production system and major topics in *Fundamentals of Modern Manufacturing*