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

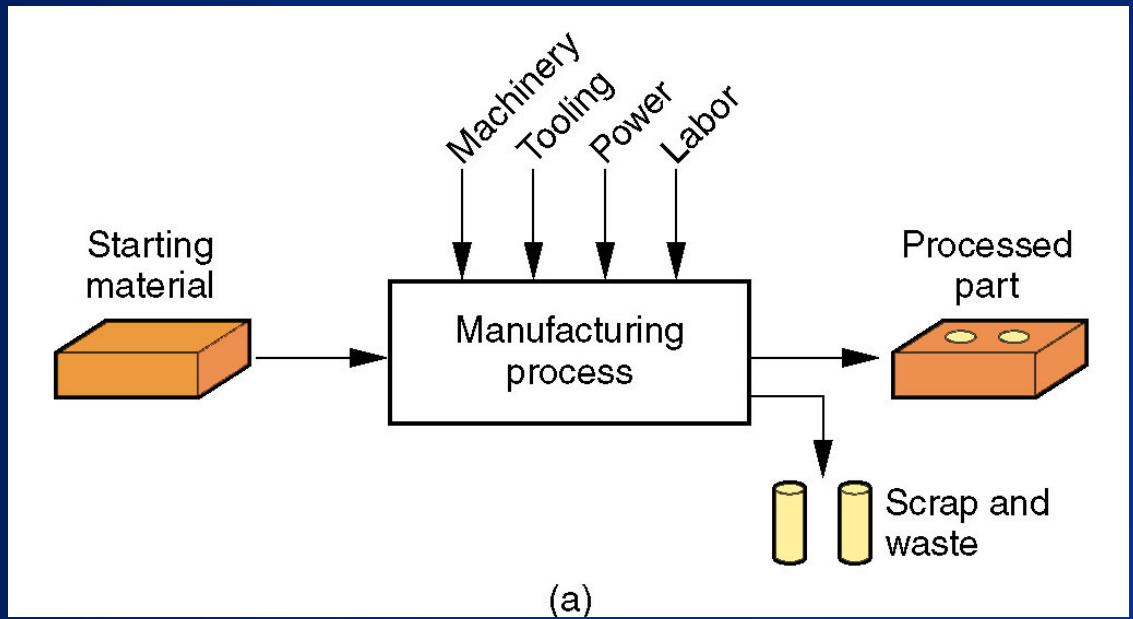


Figure 1.1 (a) Manufacturing as a technical process

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

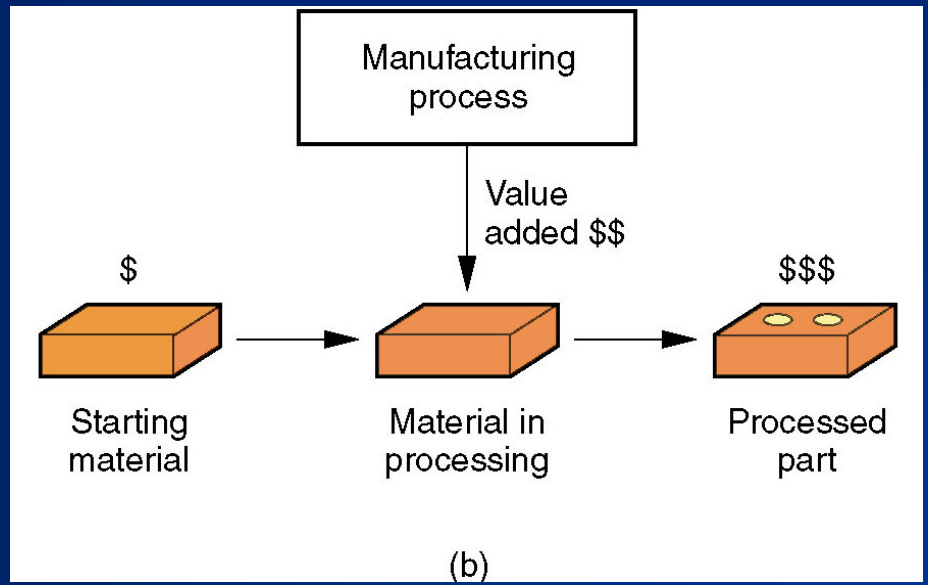


Figure 1.1 (b) Manufacturing as an economic process

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:

Production range	Annual Quantity *Q*
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

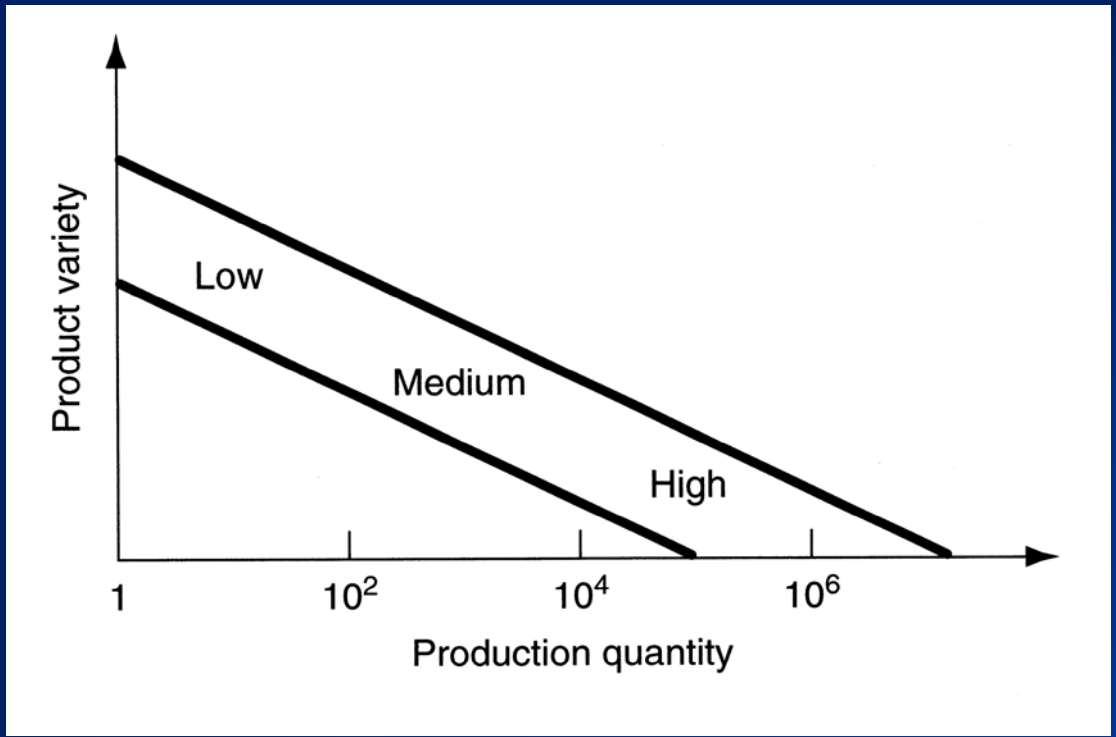


Figure 1.2 -
P-Q Relationship

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

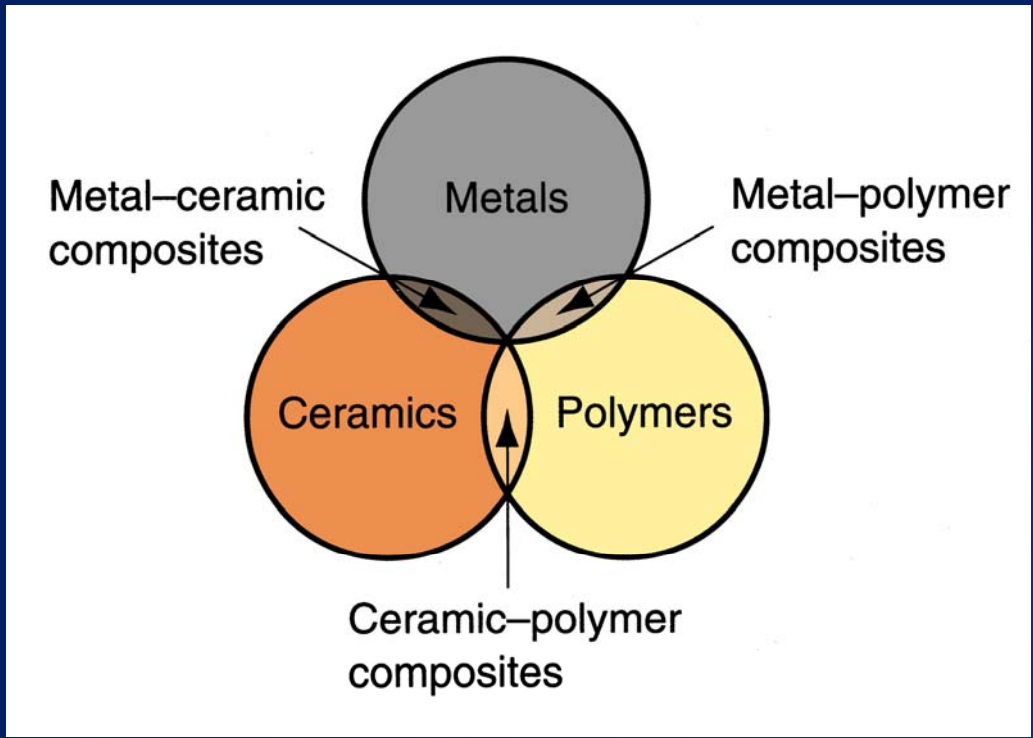


Figure 1.3 – Venn diagram of three basic Material types plus composites

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 (Al_2O_3)
  2. Glasses – mostly based on silica (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

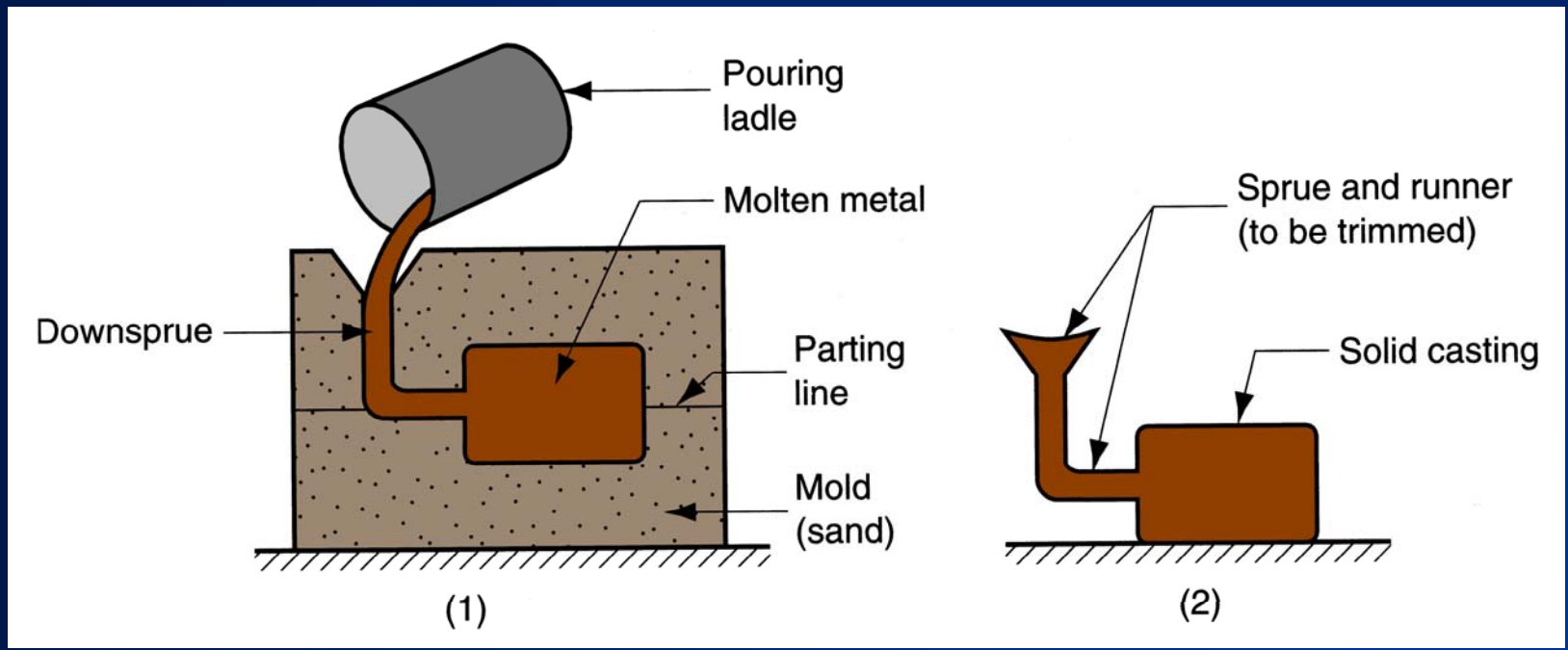
- Three categories of processing operations:
  1. Shaping operations - alter the geometry of the starting work material
  2. Property-enhancing operations - improve physical properties of the material without changing its shape
  3. Surface processing operations - performed to clean, treat, coat, or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

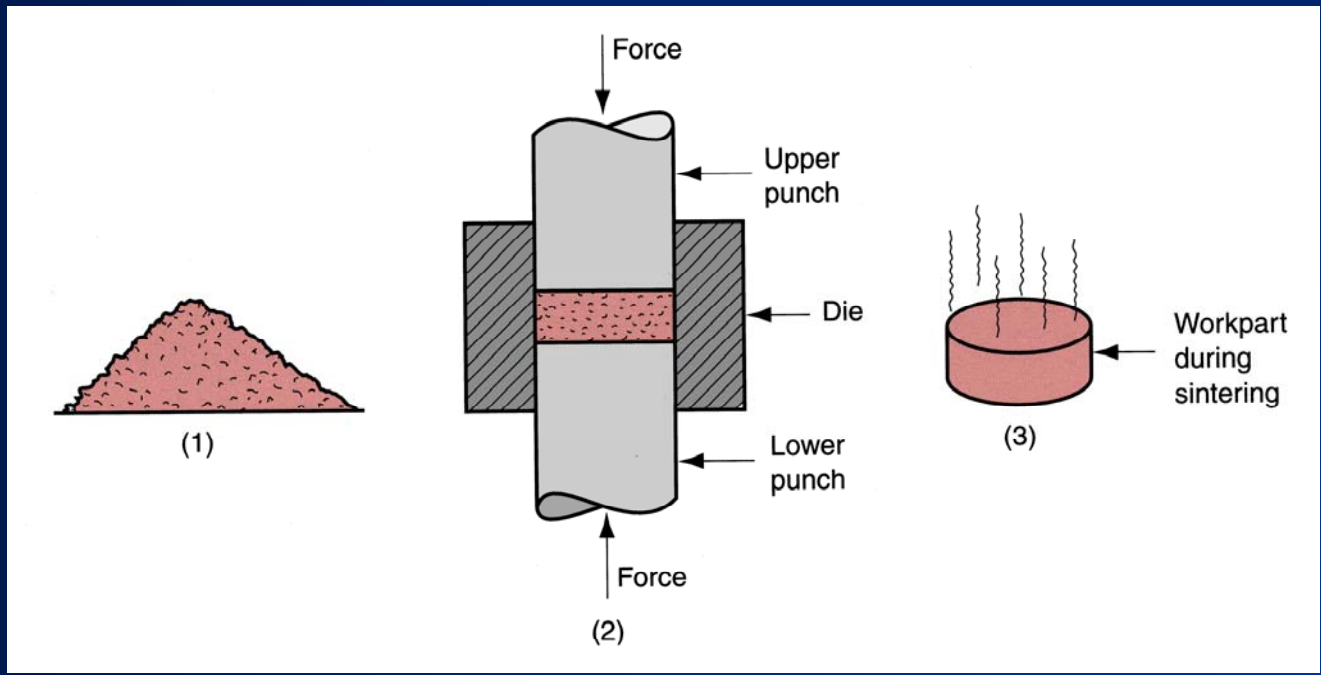
Solidification Processes

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



Particulate Processing

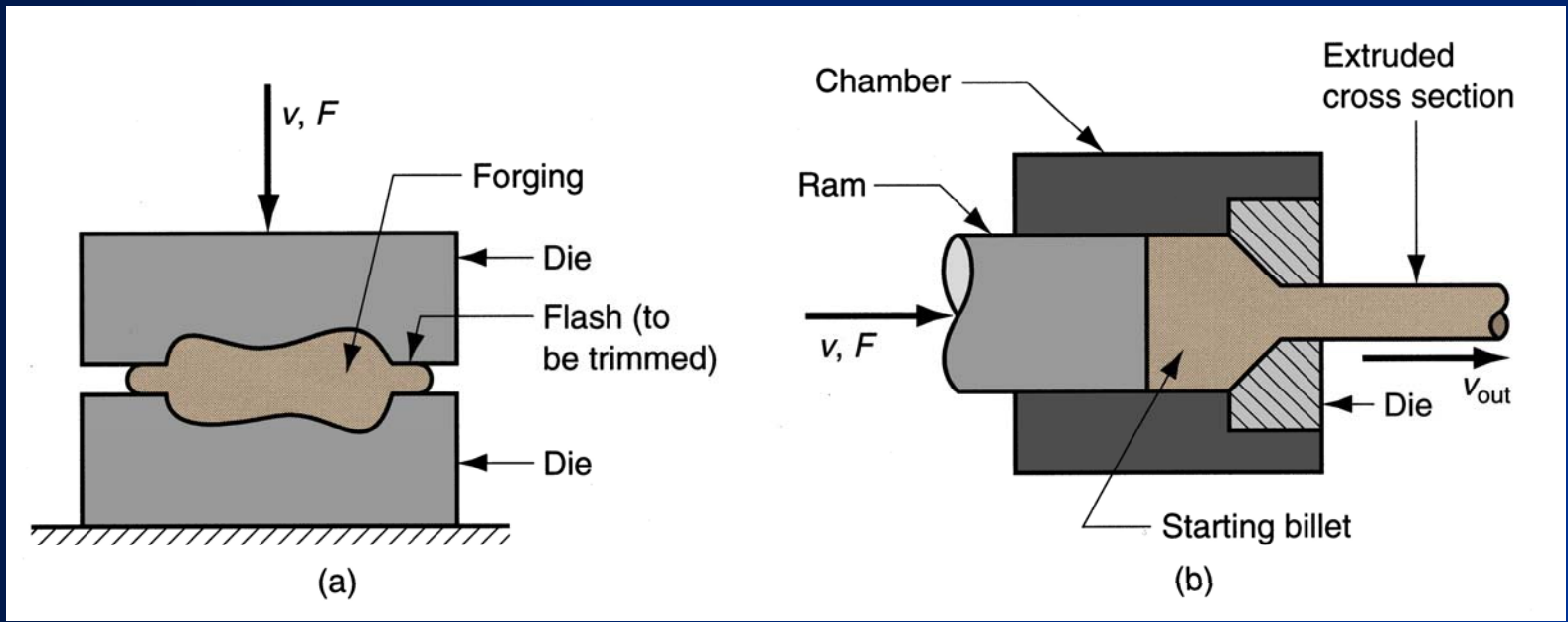
- Starting materials are powders of metals or ceramics
- Usually involves pressing and sintering, in which powders are first squeezed in a die cavity and then heated to bond the individual particles



Deformation Processes

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

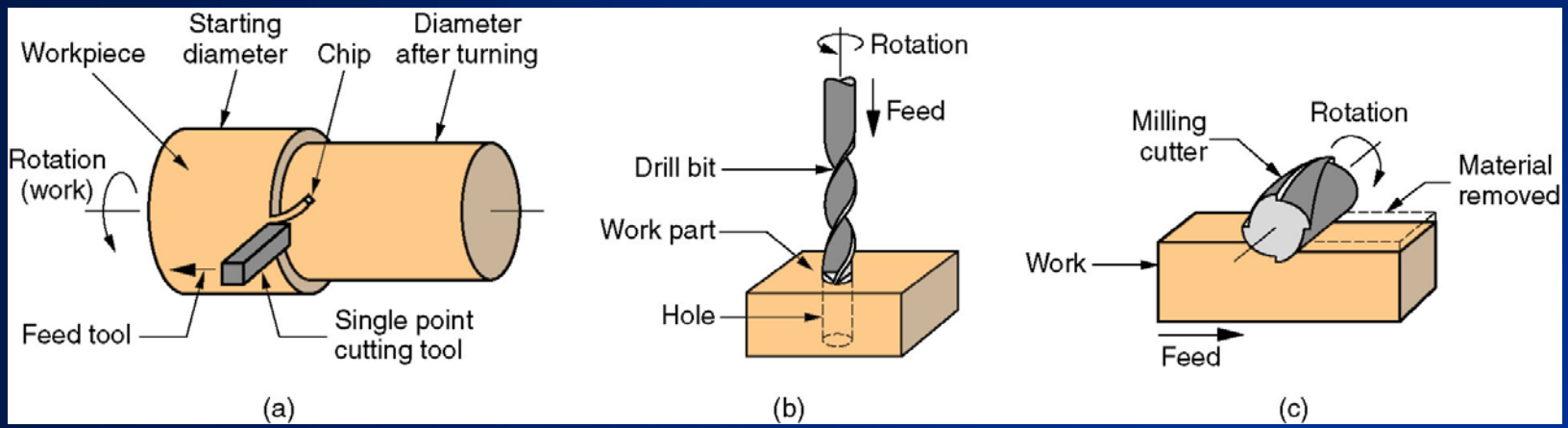
- Examples: (a) forging, (b) extrusion



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

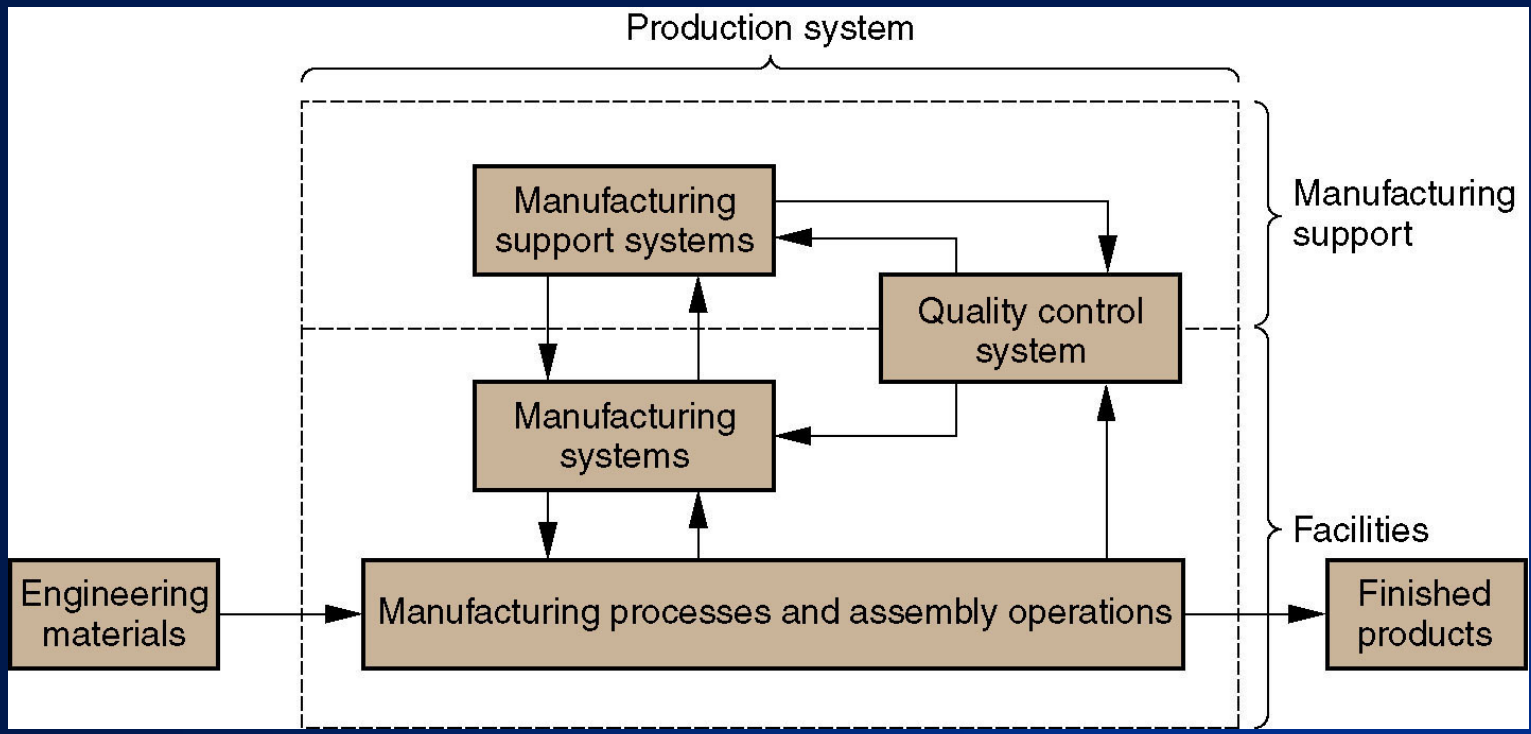


Figure 1.10 – Overview of production system and major topics in ***Fundamentals of Modern Manufacturing***