Tishk International University
Mechatronics Engineering Department
Manufacturing Technology Week 1 23/10/2025

# Introduction to Manufacturing Technology

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# Outline

- Students Obligation
- Syllabus
- Assessment
- Introduction

# Assessments

- Quiz 10%
- Homework 10%
- Participate 5%
- Report 10%
- Midterm 25%
- Final 40%

# Manufacturing technology

**Manufacturing technology** refers to the **tools, machines, equipment, and systems** used to make products efficiently and accurately.

- Manufacturing is the transformation of raw materials into useful products through physical and chemical processes. "Manufacturing connects **materials science** and **engineering practice**."
- Materials selection and manufacturing route are interdependent, together they define product performance and cost.
- PSPP Paradigm: "The four key relationships"

**[Processing] → [Structure] → [Properties] → [Performance]**

# Manufacturing Defined

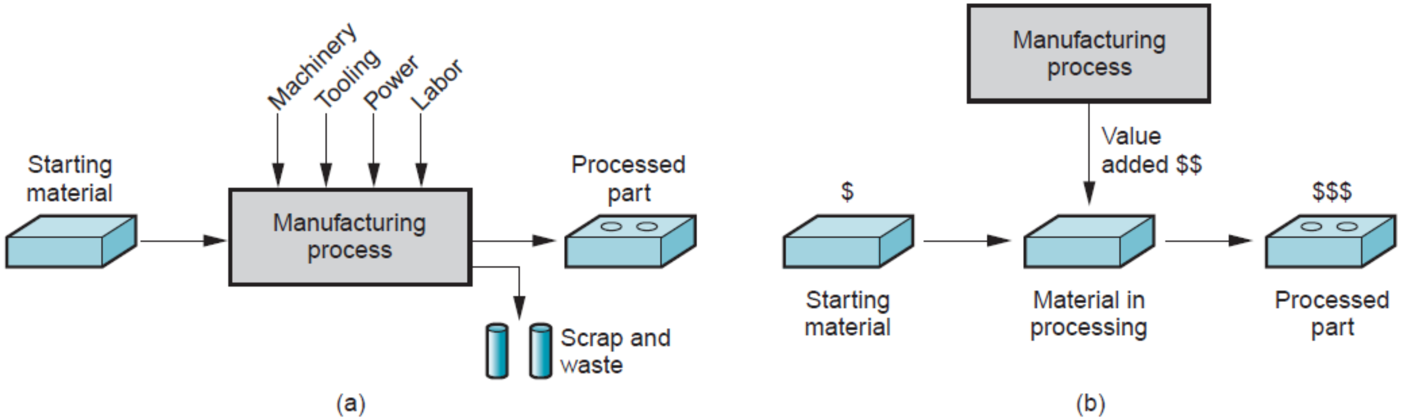



**FIGURE 1.1** Two ways to define manufacturing: (a) as a technical process, and (b) as an economic process.

**Manufacturing:**

•**Technologically:** Changing a material's **shape, properties, or appearance** and assembling parts using **machines, tools, power, and labor**.

•**Economically:** Adding **value** to materials through processing or assembly.

•**Key idea:** Manufacturing transforms raw materials into **more valuable products** (e.g., iron → steel, sand → glass, plastic → chair).

•Often used interchangeably with **production**, though production is broader.

- In this context, **“economically”** refers to the **value added to a material** through manufacturing.
- It’s not about money directly, but about **increasing the usefulness or worth** of a material.
- For example:
  - Iron ore is just raw material → when converted to steel, it becomes more valuable.
  - Sand → Glass → usable windows or bottles.
  - Plastic → molded chair → a functional product with higher value than the raw plastic.
- So, **economically** means looking at manufacturing from the perspective of **how much value or utility is added** to the material through processing or assembly.

# Importance of Manufacturing Processes

1. **Conversion of Raw Materials into Useful Products**
2. Improvement in Product Quality and Accuracy
3. Economic Growth and Industrial Development
4. Reduction of Production Cost
5. Innovation and Technological Advancement
6. Customization and Mass Production
7. Sustainability and Resource Efficiency

# What is the difference between Manufacturing and production

| Point | Manufacturing | Production |
|---|---|---|
| **Meaning** | Making things — changing raw materials into useful products. | The whole process of creating goods or services, including planning, making, and delivering. |
| **Focus** | Focuses only on **making physical products** using machines and tools. | Focuses on **managing and controlling** how goods are made, in the **whole system.** |
| **Type of Work** | Technical (machines, materials, and processes). | Managerial (planning, scheduling, controlling, quality). |
| **Example** | Machining a steel block to make a gear. | Managing all steps — from getting raw material to shipping the finished gear. |
| **Main Question** | *How do we make it?* | *How do we make it efficiently and deliver it on time?* |

# Historical Background

| | | |
|---|---|---|
| Before 1750 | Handcraft | Manual tools |
| 1750–1850 | 1st Industrial Revolution | Steam power, machines |
| 1850–1940 | 2nd Industrial Revolution | Electricity, assembly line |
| 1940–2000 | 3rd Industrial Revolution | Computers, automation |
| 2000–Present | 4th Industrial Revolution | AI, IoT, 3D printing |

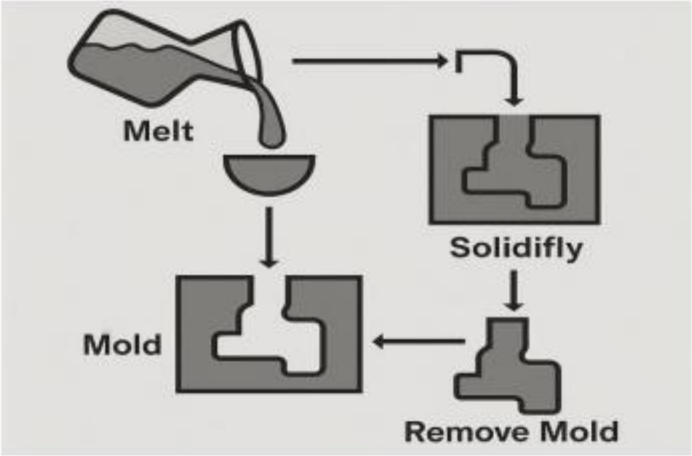
# Classifications of Manufacturing Processes

| Process Type | Main Action | Example Methods | Common Applications |
|---|---|---|---|
| Casting | Molten metal into mold | Sand casting, die casting | Engine blocks |
| Forming | Shape without cutting | Forging, rolling | Car bodies |
| Machining | Cutting/removing | Turning, milling,Drilling | Shafts, gears |
| Joining | Combine materials | Welding, riveting | Structures |
| Additive | Build layer by layer | 3D printing | Prototypes |
| Powder Metallurgy | Compress powders | Sintering | Bearings |
| Finishing | Surface improvement | Polishing, coating | Tools |
| Non-Conventional | Special energy | EDM, laser cutting | Aerospace parts |

# Overview of Manufacturing Processes

## 4.1 Casting

- Process: melt → pour → solidify → remove mold.
- Suitable for complex shapes and large components.




**Common methods:**

- Sand casting
- Die casting
- Investment casting

**Defects:** voids, shrinkage, inclusions.

### 4.2 Forming Processes

- Plastic deformation of metals under stress.
- Common methods: forging, rolling, extrusion, drawing.

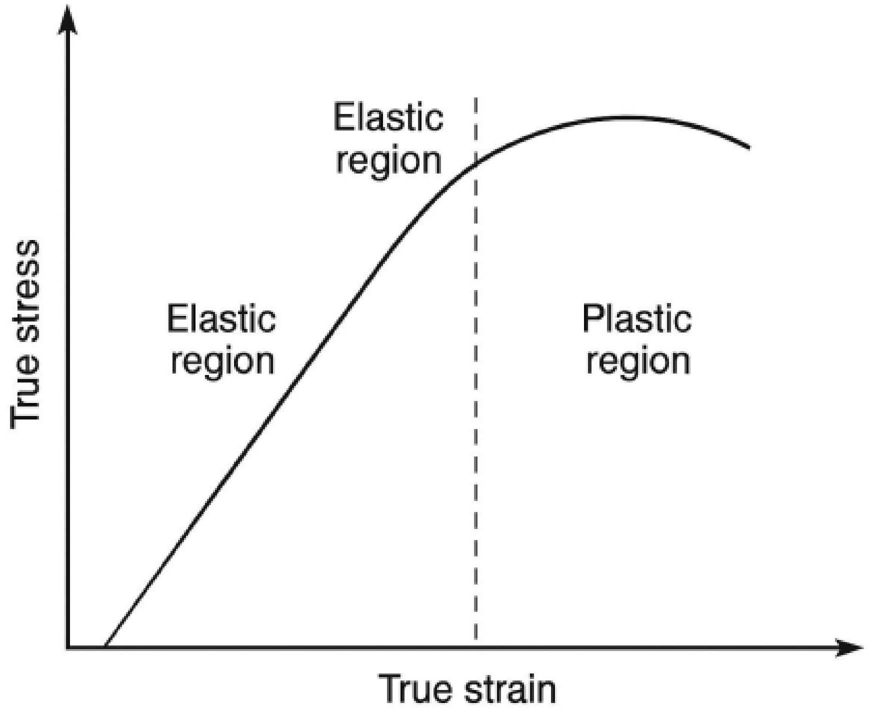
**Example:** forging refines grain structure and improves strength.

**Equation:**

$$\sigma = K\epsilon^n$$

where $K$= strength coefficient, $n$= strain hardening exponent.

**Diagram:** true stress–strain curve showing elastic and plastic regions.



### 4.3 Machining

- Subtractive process using cutting tools (turning, milling, drilling).
- Used for high precision and final shaping.
- Cutting parameters: speed (v), feed (f), depth of cut (d).

**Advantages:** tight tolerances, smooth finish.

**Limitations:** waste of material, high energy.

### 4.4 Surface Modification

- Coating, ion implantation, surface hardening.
- Improves wear, corrosion, or bioactivity.

**4.5 Additive Manufacturing (3D Printing)**

- Layer-by-layer fabrication from digital models (CAD).
- **Processes:** FDM, SLS, SLA, Binder Jetting.
- **Advantages:** complex geometry, material efficiency, rapid prototyping.

**Applications:** biomedical implants, lightweight aerospace parts.

Biomedical implants

Lightweight aerospace parts

# Steps pf Manufacturing Process

Material Selection → Preparation → Shaping → Assembly → Finishing → Inspection → Packaging & Distribution

**1. Material Selection**
•Choose the appropriate material based on the product’s **function, properties, cost, and availability**.
•Example: Steel for a car frame, plastic for a bottle.

**2. Material Preparation**
•Prepare the raw material for processing.
•May include **cutting, cleaning, melting, or mixing**.
•Example: Cutting metal sheets to size, melting plastic pellets.

**3. Shaping/Forming**
•Change the shape of the material into the desired form.
•Methods depend on the material and product:

- **Casting:** Pouring molten material into molds.
- **Forging:** Hammering or pressing metal.
- **Machining:** Cutting, drilling, milling.
- **Extrusion/Injection Molding:** For plastics or metals.

**4. Joining/Assembly**
•Combine different parts to create a complete product.
•Methods include **welding, soldering, adhesive bonding, or mechanical fastening**.
•Example: Assembling car components, electronic boards.

**5. Surface Treatment/Finishing**

- Improve **appearance, durability, or functionality**.
- Methods include **painting, plating, polishing, heat treatment, or coating**.
- Example: Painting a car, anodizing aluminum parts.

**6. Inspection/Quality Control**

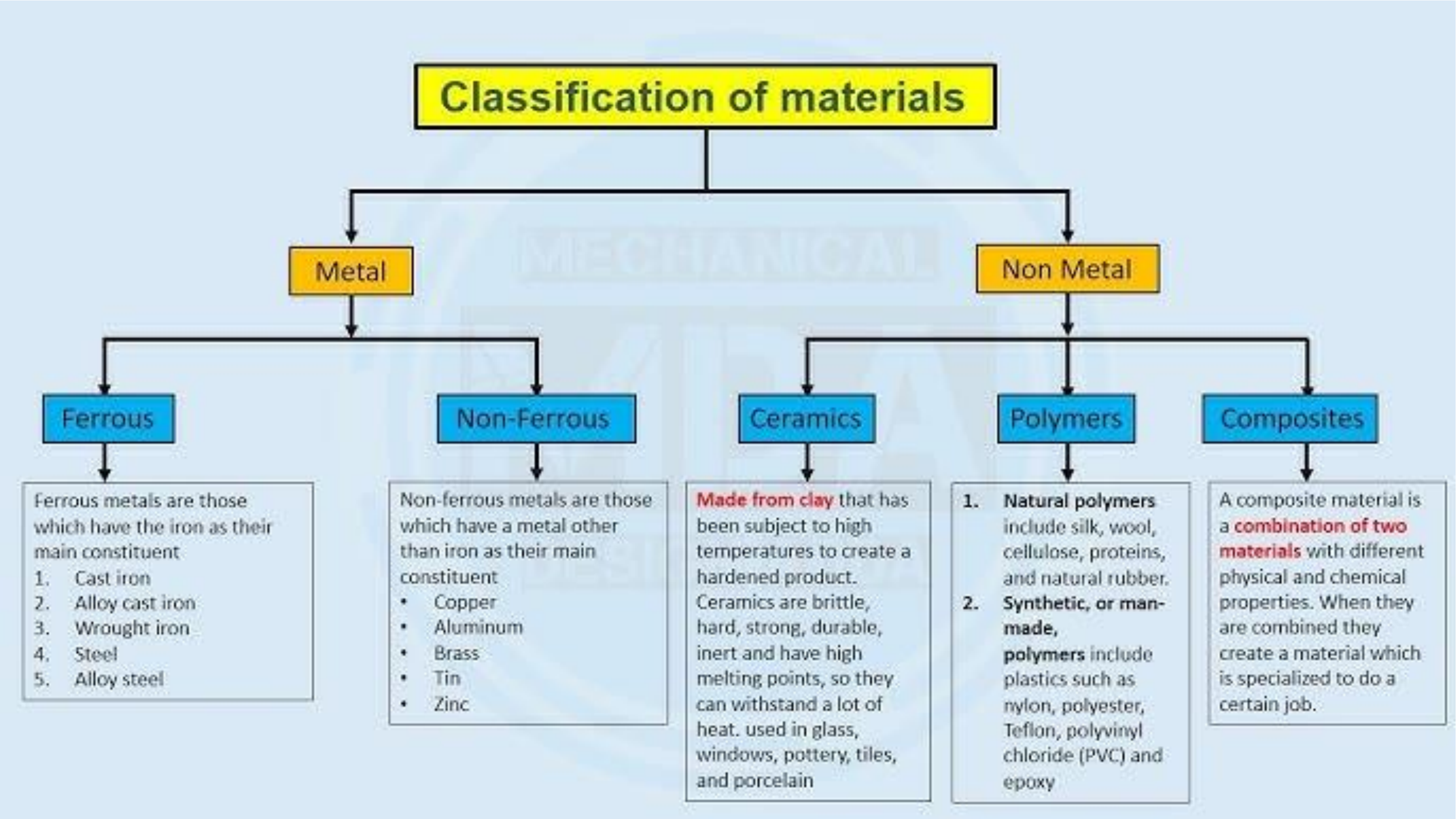
- Check for **defects, dimensions, strength, or functionality**.
- Ensures that products meet the required **standards and specifications**.
- Example: Measuring dimensions, testing tensile strength, checking electronic circuits.

**7. Packaging and Distribution**

- Prepare the product for **storage, transport, and sale**.
- Example: Packing bottles, labeling electronic devices.

# Material

In **manufacturing**, a **material** is any **substance that can be processed or transformed to make a product**. It is the **raw input** that undergoes physical, chemical, or mechanical changes during manufacturing to create parts or finished goods.


Classification of materials
Metal
Non Metal
Ferrous
Non-Ferrous
Ceramics
Polymers
Composites
Ferrous metals are those which have the iron as their main constituent
1. Cast iron
2. Alloy cast iron
3. Wrought iron
4. Steel
5. Alloy steel
Non-ferrous metals are those which have a metal other than iron as their main constituent
• Copper
• Aluminum
• Brass
• Tin
• Zinc
Made from clay that has been subject to high temperatures to create a hardened product. Ceramics are brittle, hard, strong, durable, inert and have high melting points, so they can withstand a lot of heat. used in glass, windows, pottery, tiles, and porcelain
1. Natural polymers include silk, wool, cellulose, proteins, and natural rubber.
2. Synthetic, or man-made, polymers include plastics such as nylon, polyester, Teflon, polyvinyl chloride (PVC) and epoxy
A composite material is a combination of two materials with different physical and chemical properties. When they are combined they create a material which is specialized to do a certain job.

A material property is any characteristic of a material that defines how it behaves under different conditions — such as force, temperature, electricity, magnetism, or environment.

- ✓ Materials have different properties depending on what they are used for.
- ✓ Some materials are hard, others are soft.
- ✓ Various types of properties of materials are given below.

- ➢ Physical Properties
- ➢ Chemical Properties
- ➢ Thermal Properties
- ➢ Electrical Properties
- ➢ Magnetic Properties
- ➢ Mechanical Properties of Materials

| Material Properties | Examples | What It Describes |
| --- | --- | --- |
| **1. Mechanical Properties** | Strength, hardness, ductility, toughness, elasticity | How a material behaves under load or force |
| **2. Physical Properties** | Density, melting point, color, thermal expansion | Basic physical characteristics not related to load |
| **3. Thermal Properties** | Thermal conductivity, specific heat, thermal expansion | How the material reacts to temperature changes |
| **4. Electrical Properties** | Conductivity, resistivity, dielectric strength | Ability to conduct or resist electricity |
| **5. Magnetic Properties** | Permeability, coercivity, retentivity | How the material responds to magnetic fields |
| **6. Chemical Properties** | Corrosion resistance, oxidation, chemical stability | How the material reacts with chemicals or the environment |
| **7. Optical Properties** | Transparency, reflectivity, refractive index | How the material interacts with light (important for optical or electronic components) |

# Mechanical Property

In this section, we will focus on the **mechanical properties** that play a crucial role in **manufacturing processes** and are also significant in **everyday applications**. To understand these properties, it is important to study how a material behaves when a **force causes deformation**, which can be explained using the **stress-strain diagram**.

# What is Stress–Strain Curve?

The **stress–strain curve** shows how a material behaves when a **load (force)** is applied and gradually increased until it **fractures**.
It is obtained from a **tensile test**, where a specimen is pulled and both **stress** (force per unit area) and **strain** (deformation per unit length) are recorded.

**Stress (σ)**

$$\sigma = \frac{F}{A}$$

Where:

- $F$ = applied force (N)
- $A$ = original cross-sectional area ($m^2$)

**Strain (ε)**

$$\varepsilon = \frac{\Delta L}{L}$$

Where:

- $\Delta L$ = change in length
- $L$ = original length

# Stress–Strain Curve for Ductile Material

The stress–strain curve illustrates how a **ductile material** behaves when a **tensile load** is applied gradually until it breaks.

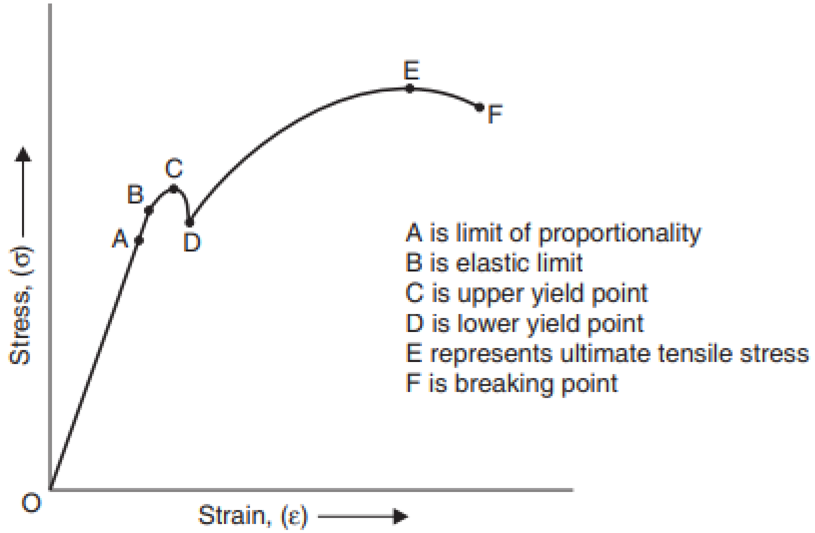



**Fig. 1.1** Stress-strain curve for ductile material

# Describing Stress strain curve for Ductile Material

| Point | Name | Explanation |
|---|---|---|
| **O–A** | **Proportional Limit** | Stress is directly proportional to strain (Hooke's Law). The slope (OA) is called **Young's Modulus (E)**. |
| **A–B** | **Elastic Limit** | The material will return to its original shape when the load is removed. Beyond this, permanent deformation starts. |
| **B–C** | **Upper Yield Point** | The material starts to yield — sudden extension occurs without an increase in load. |
| **C–D** | **Lower Yield Point** | The load remains almost constant while strain increases rapidly. |
| **D–E** | **Strain Hardening Region** | The material becomes stronger and resists further deformation. Stress increases again until it reaches the **maximum value**. |
| **E** | **Ultimate Tensile Stress (UTS)** | The maximum stress that the material can withstand before necking starts. |
| **E–F** | **Necking and Fracture Region** | The cross-sectional area begins to decrease (necking). Finally, the specimen **fractures at point F**. |

# Stress–Strain Curve for Brittle Material

**Stress–Strain Curve for Brittle Material**
A **stress–strain curve** for a **brittle material** is obtained by placing a test specimen in a **tensile testing machine** and gradually increasing the load while measuring the **extension** of the specimen.
Unlike ductile materials, the **stress–strain curve for brittle materials** shows distinct differences. Brittle materials exhibit **very little plastic deformation** before fracture. After reaching the **elastic limit**, the material **breaks suddenly** without any noticeable yielding.
A **typical stress–strain curve** for a brittle material is illustrated in **Fig. 1.3**, showing a steep and short curve that ends abruptly at the fracture point.

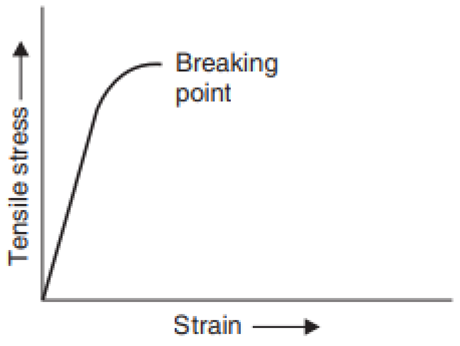


**Fig. 1.3** Stress-strain curve for brittle material

# Mechanical Property

1. **Strength** – The ability of a material to resist deformation or failure under load.
2. **Elasticity** – The ability of a material to return to its original shape after the load is removed.
3. **Plasticity** – The ability of a material to permanently deform without breaking.
4. **Ductility** – The ability of a material to be stretched into a wire before breaking.
5. **Malleability** – The ability of a material to be hammered or rolled into thin sheets.
6. **Toughness** – The ability to absorb energy and resist fracture.
7. **Hardness** – The resistance of a material to indentation, scratching, or wear.
8. **Brittleness** – The tendency of a material to break or shatter without significant deformation.
9. **Stiffness (Rigidity)** – The resistance of a material to elastic deformation under load.
10. **Resilience** – The ability of a material to absorb energy when deformed elastically and release it upon unloading.

These properties are essential in **selecting materials** for different **engineering and manufacturing applications**.

# Hardness Definition

Hardness is an important mechanical property that indicates a material's **resistance to wear, scratching, and penetration** by another object.
In earlier times, hardness was measured using a **scratch test**, where materials were ranked based on their ability to scratch one another — with **diamond** (the hardest material) placed at the top of the scale, and softer materials like **glass** ranked lower.

**Modern Hardness Testing Methods**
Today, hardness is measured using **standardized tests** that determine how well a material resists **indentation**. The principle is simple — a **harder material** allows **less penetration** under a given load. The **depth or size of the indentation** is used to calculate the hardness number.

| | *Brinell test* | *Rockwell test* | *Vicker's test* |
|---|---|---|---|
| Indentor used | Hardened steel ball of 10 mm diameter. | A diamond cone, called brale is used. | A square based diamond pyramid containing an angle of 136° between opposite faces. |
| Load applied on the indentor during test | 3000 kg for 10–15 seconds | Load is applied in two stages. First a minor load of 10 kg followed by major load of 150 kg, in case of '*C*' scale. | 5 kg–120 kg. |
| How is hardness number calculated | $\text{BHN} = \dfrac{\text{Load on ball (kg)}}{\text{Area of ball impression in mm}^2}$ | Rockwell hardness No. = 100 – 500 *t*, where *t* is depth of indentation. | VPN or VHN $= \dfrac{\text{Load}}{\text{Area of impression}}$ |
| Special comment | Depending upon material to be tested, dia of ball and load applied may change | 1. There are several hardness scales used like *A*, *B*, *C* etc. They are meant for different materials. The major load applied and even the indentor may change. 2. Hardness is never calculated. The hardness no. is read off a graduated dial. 3. For ferrous material we generally use '*C*' scale. | In practice VPN is not calculated. The indentation left by the diamond pyramid is in the shape of a rectangle. The lengths of its diagonals is measured and VPN directly found from a table against the measured value of diagonal. |

Why There are **three main hardness tests** (Brinell, Rockwell, Vickers)
Answer : because **different materials, shapes, and applications require different methods to measure hardness accurately**.
Here's why we need all three:

**1. Brinell Hardness Test**

- Uses a **big ball** to make a **large indentation**.
- **Best for:** Rough surfaces, castings, or large, coarse materials.
- **Limitation:** Not suitable for very hard or thin materials because the indentation might be too small or damage the part.

2. Rockwell Hardness Test
Measures depth of penetration with a cone or ball.
Best for: Quick industrial testing on finished parts, metals of medium thickness.
Advantage: Fast, simple, and gives a direct reading without measuring the indentation.
Limitation: Less precise for very thin or very small parts.

3. Vickers Hardness Test
Uses a tiny diamond pyramid for a very small indentation.
Best for: Thin materials, coatings, small parts, or microstructural testing.
Advantage: Extremely precise.
Limitation: More time-consuming than Rockwell.

# What is **Fracture of Materials**

**Fracture of Materials**
When a material is subjected to a **stress greater than its strength**, it eventually **fails and breaks** into two or more pieces — this is known as **fracture**.
In tensile testing, two main types of fractures are observed: **ductile fracture** and **brittle fracture**.

**1. Ductile Fracture**
- Occurs **after significant plastic deformation**.
- The material undergoes noticeable **necking** (reduction in cross-sectional area) before breaking.
- The fracture surface usually appears **rough and fibrous**.
- Example: **Mild steel**.

**2. Brittle Fracture**
- Occurs **suddenly**, with **little or no plastic deformation**.
- Initiated by the **growth of a small internal crack** until the material fractures completely.
- The fracture surface appears **flat and shiny**.
- Example: **Cast iron or glass**.

**3. Other Types of Fracture**

Apart from ductile and brittle failures, materials can also fail due to:

- **Fatigue Fracture:**

Caused by **repeated or fluctuating stresses** over time, even if the stress level is below the material's ultimate strength.

Common in rotating shafts, springs, and aircraft components.

- **Creep Fracture:**

Occurs when a material is subjected to **constant stress at high temperature** for a long period.

The material **slowly deforms** and eventually fractures.

Seen in turbine blades and steam pipes.

# Ferrous Material

**1. Introduction**

- **Ferrous materials** are metals that **contain iron** as their main element.
- **Non-ferrous materials** do not contain significant iron.
- Ferrous materials are **strong, hard, and inexpensive**, but **prone to corrosion and rust**.
- Their **properties can be improved** by **heat treatment** or by **adding alloying elements**.

2. Iron and Steel Iron (Fe) is soft and pure; melting point ≈ 1540°C.Steel is an alloy of iron and carbon (0–2%); stronger and harder than pure iron. The hardness and strength increase with carbon content (up to about 1.3%).Cementite ($Fe_3C$) makes steel hard but brittle.

# Plain Carbon Steel Types:

| Type | Carbon % | Properties | Common Uses |
|---|---|---|---|
| Low Carbon (Dead Mild) | < 0.15 | Very ductile, soft, weldable | Tubes, thin sheets |
| Mild Steel | 0.15–0.3 | Good strength, weldable | Structural works |
| Medium Carbon | 0.3–0.7 | Strong, less ductile | Shafts, axles, tools |
| High Carbon | 0.7–1.3 | Very hard, brittle | Cutting tools, dies |

**As carbon % increases → Strength ↑, Hardness ↑, Ductility ↓**

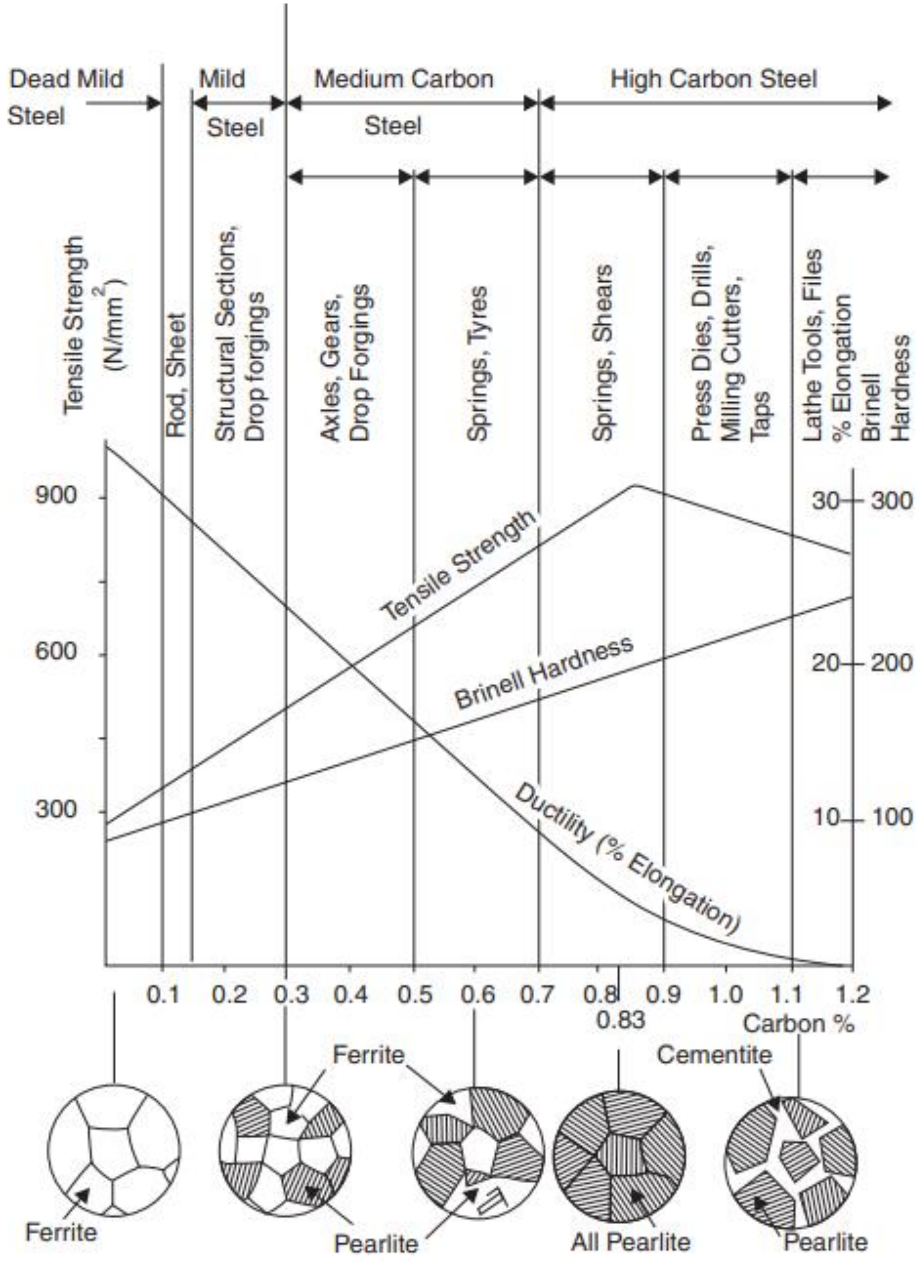



**Fig. 2.1** Microstructure, mechanical properties, and uses of plain carbon steels

# Graph Summary (Fig. 2.1)

The **graph shows the relationship** between **carbon content** and:

- **Tensile strength** → increases with carbon %.
- **Brinell hardness** → increases with carbon %.
- **Ductility (% elongation)** → decreases with carbon %.

It visually demonstrates how higher carbon makes steel stronger but less ductile.

**Wrought Iron**

- **Purest form of iron**, contains very little carbon and slag.
- **Soft, tough, malleable**, but expensive — now rarely used.
- Used in **chains, hooks, old gates**.

# Cast Iron

**Cast Iron**
•**Carbon > 2% (typically 3–4%)**, much in **graphite form**.
•**Produced in cupola furnaces** using pig iron and scrap.
•**Properties:** brittle, high compressive strength, easy to cast and machine, corrosion resistant.

| Type | Carbon Form | Characteristics | Uses |
|---|---|---|---|
| Grey | Graphite flakes | Brittle, self-lubricating | Machine beds, pipes |
| White | Cementite | Very hard, brittle | Rolls, malleable iron base |
| Malleable | Treated white iron | Tough, ductile | Fittings, small parts |
| Nodular | Graphite spheres (Mg added) | Strong, ductile | Gear housings, crankshafts |
| Alloy | With Ni, Cr, Mo, etc. | Wear & heat resistant | Engine parts, piston rings |

**Alloy Steels**

- Contain alloying elements to improve specific properties.
- **Advantages:**
  - Better **hardenability** and **strength**
  - **Corrosion resistance** (e.g. stainless steel)
  - **Red hardness** (for cutting tools)
  - Improved **toughness** and **heat resistance**

**Major Types:**

1. **Stainless Steels**
   1. **Ferritic:** cheap, magnetic, Cr 6–12%, used in coins, dairy equipment.
   2. **Martensitic:** hardenable, used for knives, screws.
   3. **Austenitic (18/8):** best corrosion resistance, used in utensils, chemical plants.
2. **Tool Steels**
   1. Designed for **hardness and red hardness**.
   2. **High-Speed Steel (HSS):** retains hardness up to 625°C; used for cutting tools.
   3. Composed of **W, Cr, V, Mo, C**.
3. **Special Alloy Steels**
   1. **Mn Steel:** work-hardening, wear-resistant (railway crossings).
   2. **Ni Steel:** corrosion resistant, used in turbine blades.
   3. **Cr Steel:** strong, used in heaters.
   4. **Si Steel:** magnetic, used in electrical machines.

# Heat Treatment of Carbon Steels

| Process | Purpose | Method | Effect |
| --- | --- | --- | --- |
| **Annealing** | Soften, relieve stress | Heat → soak → cool slowly | Increases ductility |
| **Normalizing** | Refine grains | Heat → air cool | Improves strength & structure |
| **Hardening** | Increase hardness | Heat → quench | Increases hardness, decreases ductility |
| **Tempering** | Reduce brittleness | Reheat → cool | Balances hardness & toughness |
| **Case Hardening** | Harden surface only | Add carbon to surface | Hard outer layer, soft core |

# References

Gupta, K. and Gupta, M.K. eds., 2020. *Optimization of manufacturing processes*. Cham, Switzerland: Springer International Publishing.