4. Plain Carbon steel / carbon steel

- Plain carbon steel is a type of steel having a maximum carbon content of 2.0% along with small percentages of sulphur, phosphorus and manganese etc.
- Most widely used kind of steel.
- Numerous applications because of good workability, castability and machinability.
- The properties of carbon steel depend primarily on the amount of carbon it contains.
- Most carbon steel has a carbon content of less than 1% practically.
- Carbon steel is made into a wide range of products, including structural beams, car bodies, kitchen appliances, and cans.

4.1.1 Classification of Carbon steel

- Plain carbon steel can be divided in to various classes based on

I. Carbon content
II. Applications
III. Steel manufacturing methods

(i) Based on carbon content

A. Low carbon steel or mild steel

- containing carbon up to 0.3%.
- Improvement in the ductility by heat treatment is concerned but has no effect in respect of its strength properties.
- Most stampings made from these steels
- Bullets, nuts and bolts, chains, etc that do not need great strength

B. Medium carbon steels

- Having carbon content ranging from 0.25 to 0.60%, improves in the machinability by heat treatment.
- It must also be noted that this steel is especially adaptable for machining or forging and where **surface hardness is desirable**.
- Can be used in most machine elements, car axles, rails and other parts that require strong metal.

C. High carbon steels

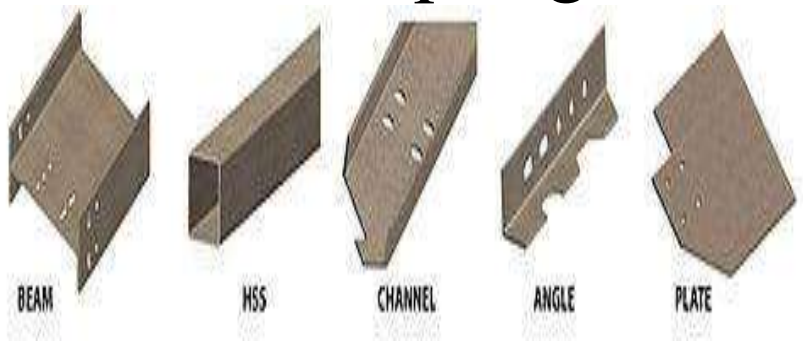
- Steel-containing carbon in the range of 0.60 to 1.5% and is especially classed as high carbon steel.
- In the fully heat-treated condition it is very hard and it will withstand high shear and wear and will thus be subjected to little deformation.
- Used in applications like cutting tools or press machinery where surface subject to abrasion – tools, knives, chisels

(ii) Based on application

- Steel may be classified in to:

  Structural steel, tool steel etc.

- There are six groups of tool steels: water-hardening, cold-work, shock-resisting, high-speed, hot-work, and special purpose. The choice of group to select depends on cost, working temperature, required surface hardness, strength, shock resistance, and toughness requirements.
- These can be further subdivided on the basis of specific application for ex. Rail steel, spring steel, boiler steel, sheet steel, etc



(iii) Based on Manufacturing Process

- Steel may be manufactures by any one of the following ways and are classified accordingly.
- For example steel manufactured using acid Bessemer process is called "*Bessemer Steel"*
- Following are the types of steel based on manufacturing method

I. Bessemer Steel
II. Open Hearth Steel
III. Electric furnace Steel
IV. Crucible Steel

PLAIN CARBON STEELS

Carbon %	Properties	Applications
0.01 - 0.10	• Soft, ductile • No useful hardening by heat treatment except by normalizing, but can be work-hardened. • Weldable.	• Pressings where high formability required
0.10 - 0.25	• Strong, ductile • No useful hardening by heat treatment except by normalizing, but can be work-hardened. • Weldable.	• General engineering uses for a mild steel
0.25 - 0.60	• Very strong • Heat treatable to produce a wide range of properties in quenched and tempered conditions. • Difficult to weld. • Can become brittle below room temperature.	• Bars and forgings • Connecting rods • Springs • Hammers • Axle • Shafts requiring strength and toughness.

PLAIN CARBON STEELS

Carbon %	Properties	Applications
0.60 - 0.90	• Strong, whether heat treated or not. • Ductility lower when less carbon is present	• Used where maximum strength rather than toughness is important. • Tools, wear resisting components (piano wire and silver steels are in this group).
0.90 - 1.50	• Wear resistant and can be made very hard at expense of toughness and ductility. • Cannot be welded. • Tend to be brittle if the structure is not carefully controlled	• Cutting tools like wood chisels, files, saw blades.

5. Alloy steel

- **Alloy steel** is steel that is alloyed with a variety of elements in total amounts between 1.0% and 50% by weight to improve its mechanical properties.

- Plain carbon steels are relatively cheap, but have a number of Property limitations.

These include:

1. Cannot be strengthened above about 690 N/mm^2 without loss of ductility and impact resistance.
2. Not very hardenable i.e. the depth of hardening is limited.
3. Low corrosion and oxidation resistance.
4. Have poor impact resistance at low temperatures.

•Limited application of plain carbon steel can be minimized by addition of one or more elements.

•The properties of steel depends on both carbon and alloying elements.

•The principal alloying elements used are: manganese (Mn), nickel (Ni), chromium (Cr), molybdenum (Mo), tungsten (W), vanadium (V), cobalt (Co), silicon (Si), boron (B), copper (Cu), aluminium (Al), titanium (Ti) and niobium (Nb).

5.1 EFFECT OF ALLOYING ELEMENTS ON PROPERTIES OF STEEL

Type of Property	Properties	Selection of Alloying element for improving properties
Physical	Grain Size	Mo, V
Chemical	Corrosion Resistance	Cr, Ni
Mechanical	Strength, Hardness, Fatigue Elasticity	Mo, V, Cr, Ni, C, W Si
Electrical	-	-
Thermal	Co-eff. Of thermal expansion	Ni
Magnetic	Permeability	Si, Ni, Co
Optical	-	-
Technological	Machinability	Mn, S, Pb

1. **Molybdenum (Mo) :** It provides hardenability, increases strength and impact resistance of high temperature (creep strength), retards grain growth at high temperature.
2. **Vanadium (V)** : It is a strong de-oxidizer, it increases hardenability, it refines the grain and reduces grain growth, it improves fatigue resistance**.**
3. **Chromium (Cr)** : It improves corrosion resistance, increases hardenability, provides strength, wear resistance and oxidation resistance at elevated temperatures.
4. **Nickel (Ni) :** It provides toughness, corrosion resistance, deep hardening and increases impact resistance at very low temperature.
5. **Carbon :**This increases hardness and strength.

6. **Tungsten :** It forms hard abrasion resistance particles, imparts red-hardness, increases hardenability to a great extent. It is an important alloying element in HSS.

7. **Silicon :** It acts as de-oxidizer, promotes resistance to high temperature oxidation, increases strength and hardness, increases magnetic permeability and decreases hysteresis loss.

8. **Manganese** : It de-oxidizes, contributes to strength and hardness. It counter-effects sulphur, increases hardenability, decreases the critical cooling rate.

9. **Sulphur :** It is generally considered as an impurity. It combines with iron to form FeS. This causes failure at high temperature. S% should be limited to 0.05% except in one special steel called “free cutting steel”

5.2 Classification of alloy steel

- Alloy steel can be classified on the basis of

1. Amount of alloying elements
2. Principal alloying element
3. Application of steel
4. Microstructure of steel

1. Based on amount of alloying elements

- Low alloy steel (0-5 % alloying addition)
- Medium alloy steel (5-10 % alloying addition)
- High alloy steel (more than 10 % alloying addition)

2. Based on principal alloying elements

- Ni steels
- Cr steel
- Cr-Ni steels
- Ni-Cr-Mo steels
- Ni-Cr-V steel

3. Based on application of steel

- Spring steel
- Bearing steel
- Corrosion resistant steel
- Creep resistance steel
- Die steel
- Cryogenic steel

4. Based on Microstructure of steel

- Pearlitic steel
- Ferritic steel
- Martensitic steel
- Bainitic steel
- Austenitic steel

5.3 Properties of alloy steel

- Good Hardenability
- Good Machinability
- Strength is achieved by heat treatment
- Higher Corrosion resistance
- Wear resistance
- Retention of hardness and strength at high temperature.

5.4 Application of alloy steel

- Structural purpose
- Chemical industries
- Electrical machines
- Springs
- Metal cutting tools
- High temperature application