- The term 'high alloy steels' is used for alloy steels containing more than 10% of alloying elements. The designation of high alloy steels consists of the following quantities:
- (i) a letter 'X';
- (ii) a fi gure indicating 100 times the average percentage of carbon;
- (iii) chemical symbol for alloying elements each followed by the fi gure for its average percentage content rounded off to the nearest integer; and
- (iv) chemical symbol to indicate a specially added element to attain desired properties, if any.
- As an example, X15Cr25Ni12 is a high alloy steel with 0.15% carbon, 25% chromium and 12% nickel. As a second example, consider a steel with the following chemical composition:

- carbon = 0.15–0.25%
- silicon = 0.10–0.50%
- manganese = 0.30–0.50%
- nickel = 1.5–2.5%
- chromium = 16–20%
- The average content of carbon is 0.20%, which is denoted by a number (0.20 ¥ 100) or 20. The major alloying elements are chromium (average 18%) and nickel (average 2%). Hence, the designation of steel is X20Cr18Ni2.

- PLAIN CARBON STEELS
- Depending upon the percentage of carbon, plain carbon steels are classifi ed into the following three groups:
- (i) Low Carbon Steel Low carbon steel contains less than 0.3% carbon. It is popular as 'mild steel'. Low carbon steels are soft and very ductile. They can be easily machined and easily welded. However, due to low carbon content, they are unresponsive to heat treatment.
- (ii) Medium Carbon Steel Medium carbon steel has a carbon content in the range of 0.3% to 0.5%. It is popular as machinery steel. Medium carbon steel is easily hardened by heat treatment. Medium carbon steels are stronger and tougher as compared with low carbon steels. They can be machined well and they respond readily to heat treatment.
- (iii) High Carbon Steel High carbon steel contains more than 0.5% carbon. They are called hard steels or tool steels. High carbon steels respond readily to heat treatments. When heat treated, high carbon steels have very high strength combined with hardness.
- They do not have much ductility as compared with low and medium carbon steels. High carbon steels are diffi cult to weld. Excessive hardness is often accompanied by excessive brittleness. Plain carbon steels are available in the form of bar, tube, plate, sheet and wire. The mechanical properties of plain carbon steels7 are given in Table 2.2.

Table 2.2 *Mechanical properties of plain carbon steels*

Grade	*Tensile strength (Min.) (N/mm^2)*	*Yield strength (Min.) (N/mm^2)*	*Hardness (HB)*	*Elongation %*
7C4	320	–	–	27
10C4	340	–	–	26
30C8	500	400	179	21
40C8	580	380	217	18
45C8	630	380	229	15
50C4	660	460	241	13
55C8	720	460	265	13
60C4	750	–	255	11
65C6	750	–	255	10

- The guidelines for deciding carbon content in plain carbon steels are as follows:
- (i) In applications like automobile bodies and hoods, the ability of the material to deform to a grater extent or 'ductility' is the most important consideration. Such a material should have high ductility. Ductility is measured in terms of percentage elongation. It is observed from Table 2.2, that lower the percentage of carbon, higher is the percentage of elongation or ductility. Therefore, a plain carbon steel, like 7C4, which has a lower percentage of carbon and a higher percentage of elongation, is selected for these parts.
- (ii) In applications like gears, machine tool spindles and transmission shafts, strength, toughness and response to heat treatment are important considerations. In these components, the surface is heavily stressed, while the stresses in the core are of comparatively small magnitude. These components require a soft core and a hard surface. This is achieved by case hardening of gears, shafts and spindles. Medium and high carbon steels, such as 40C8, 45C8, 50C4, 55C8, and 60C4 which are stronger, tougher and respond readily to heat treatment are, therefore, selected for these components. They can also be machined well to the required accuracy.
- (iii) Spring wires are subjected to severe stress and strength is the most important consideration in selection of their material. High carbon steel, such as 65C6, having maximum tensile strength, is selected for helical and leaf springs.
- (iv) Low and medium carbon steels can be satisfactorily welded. However, low carbon steels are the most easily welded. Higher the percentage of carbon in steel, more diffi cult it is to weld. Therefore, welded assemblies are made of low and medium carbon steels.
- (v) Low and medium carbon steels can be satisfactorily forged. However, low carbon steels that are very soft and ductile, are the most easily forged. Higher the percentage of carbon in steel, the more diffi cult it is to forge the part. Therefore, forged components such as levers, rocker arm, yoke or tie rod are made of low carbon steel 30C8. However, there are some forged components like connecting rod and crankshaft, which also require heat treatment after forging. They are made of medium carbon steel 40C8, which responds readily to heat treatment.
- (vi) All steels have essentially the same modulus of elasticity. Thus, if rigidity is the requirement of the component, all steels perform equally well. In this case, the least costly steel should be selected.

- Some of the important applications of plain carbon steels are as follows:
- 7C4 Components made by severe drawing operation such as automobile bodies and hoods
- 10C4 Case hardened components such as cams and cam shaft, worm, gudgeon pin, sprocket and spindle
- 30C8 Cold formed and case hardened parts such as socket, tie rod, yoke, lever and rocker arm
- 40C8 Transmission shaft, crank shaft, spindle, connecting rod, stud and bolts
- 45C8 Transmission shaft, machine tool spindle, bolts and gears of large dimensions
- 50C4 Transmission shaft, worm, gears and cylinder
- 55C8 Components with moderate wear resistance such as gears, cam, sprocket, cylinder and key
- 60C4 Machine tool spindle, hardened bolt and pinion
- 65C6 Coil a nd leaf springs

- FREE CUTTING STEELS
- Steels of this group include carbon steel and carbon–manganese steel with a small percentage of sulphur.
- Due to addition of sulphur, the machinability of these steels is improved.
- Machinability is defi ned as the ease with which a component can be machined.
- It involves three factors—the ease of chip formation, the ability to achieve a good surface fi nish and ability to achieve an economical tool life.
- Machinability is an important consideration for parts made by automatic machine tools.
- Typical applications of free cutting steels are studs, bolts and nuts.
- Mechanical properties of free cutting steels8 are given in Table 2.3.

- ALLOY STEELS

- Alloy steel is defi ned as carbon steel to which one or more alloying elements are added to obtain certain benefi cial effects. The commonly added elements include silicon, manganese, nickel, chromium, molybdenum and tungsten. The term ‘alloy steels’ usually refers to ‘low’ alloy steels containing from about 1 to 4 per cent of alloying elements. On the other hand, stainless and heatresisting steels are called ‘high’ alloy steels. Plain carbon steels are successfully used for components subjected to low or medium stresses. These steels are cheaper than alloy steels. However, plain carbon steels have the following limitations
- :(i) The tensile strength of plain carbon steels cannot be increased beyond 700 N/mm2 without substantial loss in ductility and impact resistance.
- (ii) Components with large section thickness cannot be produced with martensitic structure. In other words, plain carbon steels are not deep hardenable.
- (iii) Plain carbon steels have low corrosion resistance.
- (iv) Medium carbon steels must be quenched rapidly to obtain a fully martensitic structure. Rapid quenching results in distortion and cracking in heat-treated components.
- (v) Plain carbon steels have poor impact resistance at low temperatures. To overcome these defi ciencies of plain carbon steels, alloy steels have been developed. Alloy steels cost more than plain carbon steels.
- However, in many applications, alloy steel is the only choice to meet the requirements. Alloy steels have the following advantages:
- (i) Alloy steels have higher strength, hardness and toughness.
- (ii) High values of hardness and strength can be achieved for components with large section thickness.
- (iii) Alloy steels possess higher hardenability, which has great signifi cance in heat treatment of components.
- (iv) Alloy steels retain their strength and hardness at elevated temperatures.
- v) Alloy steels have higher resistance to corrosion and oxidation compared with plain carbon steels.