- Alloying elements can affect constitution, characteristics and behaviour of these steels.
- The effects of major alloying elements are as follows:
- (i) Silicon Silicon is present in almost all steels. It increases strength and hardness without lowering the ductility. Silicon is purposely added in spring steel to increase its toughness.
- (ii) Manganese Most steels contain some manganese remaining from the deoxidisation and desulphurisation processes. However, when it exceeds 1 per cent, it is regarded as an alloying element. Manganese is one of the least expensive alloying elements. It increases hardness and strength. It also increases the depth of hardening. Manganese is an important alloying element in free cutting steels.
- (iii) Nickel Nickel increases strength, hardness and toughness without sacrifi cing ductility. It increases hardenability of steel and impact resistance at low temperature. The main effect of nickel is to increase toughness by limiting grain growth during the heat treatment process.
- (iv) Chromium Chromium increases hardness and wear resistance. Chromium steel components can be readily hardened in heavy sections. They retain strength and hardness at elevated temperatures. Chromium steels containing more than 4 per cent chromium have excellent corrosion resistance.
- (v) Molybdenum Molybdenum increases hardness and wear resistance. It resists softening of steel during tempering and heating.
- (vi) Tungsten Tungsten and molybdenum have similar effects. It is an expensive alloying element and about 2 to 3 per cent tungsten is required to replace 1 per cent of molybdenum. It is an important alloying element in tool steels.
- Many times, a designer is faced with the aspect of choosing the correct alloying element of steels for a particular application. This is an important decision because by merely changing an alloying element, one can get totally different combinations of mechanical properties for steel

- The guidelines for selecting alloy steels are as follows:
- (i) Spring wires are subjected to severe stresses, and strength is the most important consideration in selection of their material. Silicon increases strength. Therefore, silicon steel, such as 55Si7, is selected for helical and leaf springs.
- (ii) In case of highly stressed screws, bolts and axles, high strength and toughness are important considerations. Nickel increases strength and toughness without loss of40Ni14 is used for these severely stressed components.
- (iii) In applications like gears, surface hardness, wear resistance 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. Chromium increases hardness and wear resistance. Also, chromium steels are readily hardened in heavy sections. Therefore, chromium steels, such as 40Cr4 is selected for all types of gears.
- (iv) In a number of components like gears, cams, camshafts, and transmission shafts, combined properties such as hardness and toughness, strength and ductility are required.
- This is achieved by using nickel and chromium as alloying elements and selecting proper heat treatment. Nickel–chromium steels, like 16Ni3Cr2 or 30Ni16Cr5, which combines hardness and toughness, are selected for these parts.
- Some of the important applications of alloy steels are as follows:
- 55Si7 Leaf and coil springs
- 37C15 Axle, shaft and crankshaft
- 35Mn6Mo3 Bolt, stud, axle, lever and general engineering components
- 16Mn5Cr4 Gears and shaft
- 40Cr4 Gears, axle and steering arm
- 50Cr4 Coil, laminated and volute springs
- 40Cr4Mo2 Shaft, axle, high tensile bolt, stud and popeller shaft
- 40Cr13Mo10V2 Components subjected to high tensile stresses
- 40Ni14 Severely stressed screw, nut and bolt
- 16Ni3Cr2 Gears, transmission components, cam and camshaft
- 30Ni16Cr5 Heavy duty gears
- 35Ni5Cr2 Gear shaft, crankshaft, chain parts, camshaft and planetary gears
- 40Ni6Cr4Mo2 General machine parts, nuts and bolts, gears, axles, shafts and connecting rod
- 40Ni10Cr3Mo6 High strength machine components, bolts and studs, axles and shafts, gears and crankshafts

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- SELECTION OF MATERIAL
- Selection of a proper material for the machine component is one of the most important steps in the process of machine design. The best material is one which will serve the desired purpose at minimum cost. It is not always easy to select such a material and the process may involve the trial and error method. The factors which should be considered while selecting the material for a machine component are as follows:
- (i) Availability The material should be readily available in the market, in large enough quantities to meet the requirement. Cast iron and aluminum alloys are always available in abundance while shortage of lead and copper alloys is a common experience.
- (ii) Cost For every application, there is a limiting cost beyond which the designer cannot go. When this limit is exceeded, the designer has to consider other alternative materials. In cost analysis, there are two factors, namely, cost of material and the cost of processing the material into finished goods. It is likely that the cost of material might be low, but the processing may involve costly manufacturing operations.
- (iii) Mechanical Properties Mechanical properties are the most important technical factor governing the selection of material. They include strength under static and fl uctuating loads, elasticity, plasticity, stiffness, resilience, toughness, ductility, malleability and hardness. Depending upon the service conditions and the functional requirement, different mechanical properties are considered and a suitable material is selected. For example, the material for the connecting rod of an internal combustion engine should be capable to withstand fl uctuating stresses induced due to combustion of fuel. In this case, endurance limit becomes the criterion of selection. The piston rings should have a hard surface to resist wear due to rubbing action with the cylinder surface, and surface hardness is the selection criterion. In case of bearing materials, a low coeffi cient of friction is desirable while clutch or brake lining requires a high coefficient of friction. The material for automobile bodies and hoods should have the ability to be extensively deformed in plastic range without fracture, and plasticity is the criterion of material selection.
- (iv) Manufacturing Considerations In some applications, machinability of material is an important consideration in selection. Sometimes, an expensive material is more economical than a low priced one, which is diffi cult to machine. Free cutting steels have excellent machinability, which is an important factor in their selection for high strength bolts, axles and shafts. Where the product is of complex shape, castability or ability of the molten metal to fl ow into intricate passages is the criterion of material selection. In fabricated assemblies of plates and rods, weld ability becomes the governing factor. The manufacturing processes, such as casting, forging, extrusion, welding and machining govern the selection of material. Past experience is a good guide for the selection of material. However, a designer should not overlook the possibilities of new materials.