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Chapter one : Alloy Steel

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The Effect of Alloying Element in the Steel Engineers have demanded steels with higher and higher tensile strength, together with adequate ductility. This has been particularly so where lightness is desirable. An increase in carbon content met this demand in a limited way, but even in the heat treatment condition the maximum strength is about 700 Mpa above which value a rapid full in ductility and impact strength occurs and mass effects limit the permissible section .

Heat treated alloy steel provide high strength, combined with appreciable ductility even in large sections. The use of plain carbon steels frequently necessitates water quenching accompanied by danger of distortion and cracking and even so only thin sections can be hardened throughout .

Alloy steels are essential for resisting corrosion and oxidation at elevated temperatures.

The principal alloying elements added to steel in widely varying amounts either singly or in complex mixture are nickel, chromium, manganese, molybdenum, vanadium, silicon etc.

The effect of alloying element in the steel may be one or more of the following .

1. It may go into solid solution in the iron, enhancing the strength. Fig (1.1).
2. Hard carbide may be formed.
3. It may form intermediate compounds with iron, e.g. Fe Cr (Sigma phase).
4. It may alter the critical points (temperatures). Fig (1.2)
5. It may alter the carbon content of the eutectoid Fig (1.3)
6. It may change the critical rate of cooling, which is the minimum cooling speed will produce martensite from austenite.
7. It may tend to produce adherent oxide films on the surface of the steel which increase its resistance to corrosion and oxidation of elevated temperature.

8. It may render the alloy sluggish thermal changes, increasing the stability of the hardened condition and so producing tool steel.
9. It may tend to increase creep resistance by presence of dispersion of fine carbides.

Classification of alloying metals according to their effect in the steel is difficult, because the influence varies so widely with each addition depending on the quantity used and other elements present

Element which tend to stabilize austenite are manganese nickel, cobalt, and copper. These elements alter the critical points of iron by raising the A4 point and lowering the A3 point see Fig (1.3). Thus increasing the range in which austenite is stable. Also they tend to retard the separation of carbides. They have a crystal lattice F.C.C. similar to that of γ – iron in which they are more soluble than in α – iron .

Elements which tend to stabilize ferrite are chromium, molybdenum, tungsten, vanadium and silicon. These elements alter the critical points on the binary equilibrium diagram Fig (1.3) by lowering A4 point and A3 raised until the two points merge to form "Closed gammed loop". These diminish the amount of carbon soluble in the austenite and thus tend to increase the volume of free carbides in the steel for a given carbon content.

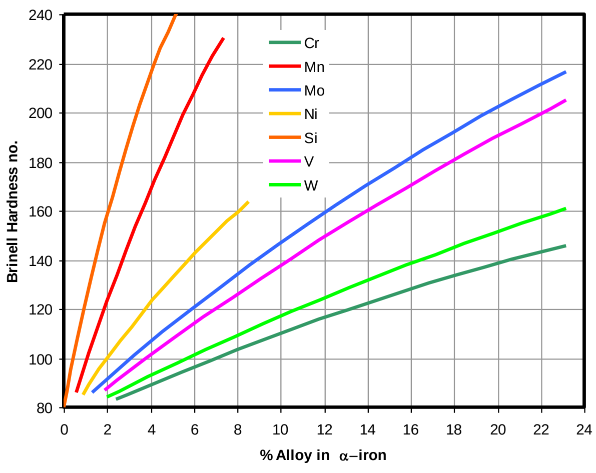


Fig. (1.1) Effect of Alloying Element on Hardness of Steel

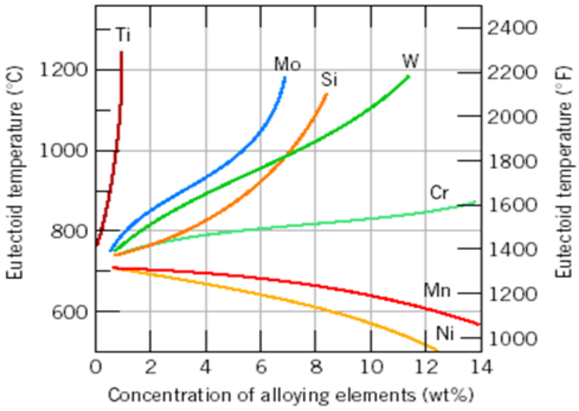


Fig. (1.2) Effect of Alloying Element on Eutectoid Temperature

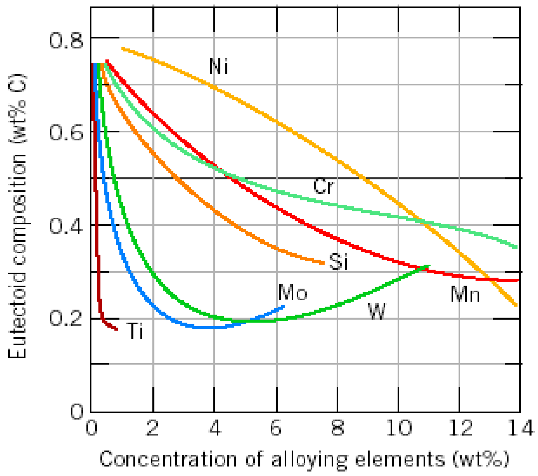


Fig. (1.3) Effect of Alloying Element on Eutectoid Carbon Content

Manganese Steel

Mangalloy was created by Robert Hadfield in 1882, becoming the first alloy steel to both become a commercial success and to exhibit behavior radically differing from carbon steel.

Manganese steel, also called Mangalloy or Hadfield steel, is an alloy steel that contains 0.8 to 1.25% carbon and 11 to 15% manganese. Manganese steel is non-magnetic steel with extreme anti-wear properties, high abrasion resistance, high impact strength, high tensile strength, and fair yield strength. The material will achieve up to three times its surface hardness during conditions of impact, without any increase in brittleness. The basic Brinell hardness of manganese steel is 220 but that with impact wear the surface hardness will increase to higher than 550. Mangalloy is heat treatable.

Applications of Manganese steel :-

Because of its self hardening properties, manganese steel has been used in the mining industry for many years – cement mixers, rock crushers, crawler treads for tractors, elevator and shovel buckets – as well as in the rail industry (switches and crossings) and other high impact environments.

World War I, Brodie helmet, made from Hadfield steel

Self-hardening definition, noting or pertaining to any of various steels that harden after heating without quenching or other treatment

Many uses of manganese steel are often limited by its difficulty in machining, sometimes it is described as zero machinability. Mangalloy can't be softened by annealing and hardens rapidly under the cutting and grinding tools, usually needs special tools to process. This material can be drilled with diamond or carbide tools, but extreme difficulty exists. It can be cut with an oxy-acetylene torch, but plasma or laser cutting is the preferred method.

Difference Between Manganese Steel and Carbon Steel - Manganese Steel vs Carbon Steel

Mangalloy was created by Robert Hadfield in 1882, it is the first alloy steel that has considerable differences in properties compared to carbon steel.

1. The first difference between manganese steel and carbon steel is that mangalloy softens rather than hardens when rapidly cooled, then restores the ductility from a work-hardened state.
2. Manganese steel is much tougher than carbon steel when heated.
3. Manganese steel can resist impact significantly longer than high carbon steel.
4. Manganese steel is less abrasion resistant than high carbon steel which has been heat treated.
5. Carbon steels gain strength from tempering, Manganese steel loses ductility when tempered.

stainless steel:-

any one of a family of alloy steels usually containing 10 to 30 percent chromium. In conjunction with low carbon content, chromium imparts remarkable resistance to corrosion and heat. Other elements, such as nickel, molybdenum, titanium, aluminum, niobium, copper, nitrogen, sulfur, phosphorus, or selenium, may be added to increase corrosion resistance to specific environments, enhance oxidation resistance, and impart special characteristics.

Most stainless steels are first melted in electric-arc or basic oxygen furnaces and subsequently refined in another steelmaking vessel .Typical properties are included in Table 1.1.

There are more than 100 grades of stainless steel. The majority are classified into five major groups in the family of stainless steels: austenitic, ferritic, martensitic, duplex, and precipitation-hardening.

Austenitic steels,

which contain 16 to 26 percent chromium and up to 35 percent nickel, usually have the highest corrosion resistance. They are not hardenable by heat treatment and are nonmagnetic. The most common type is the 18/8, or 304, grade, which contains 18 percent chromium and 8 percent nickel. Typical applications include aircraft and the dairy and food-processing industries.

ferritic steels,

contain 10.5 to 27 percent chromium and are nickel-free; because of their low carbon content (less than 0.2 percent), they are not hardenable by heat treatment and have less critical anticorrosion applications, such as architectural and auto trim.

Martensitic steels,

typically contain 11.5 to 18 percent chromium and up to 1.2 percent carbon with nickel sometimes added. They are hardenable by heat treatment, have modest corrosion resistance, and are employed in cutlery, surgical instruments, wrenches, and turbines.

Duplex stainless steels

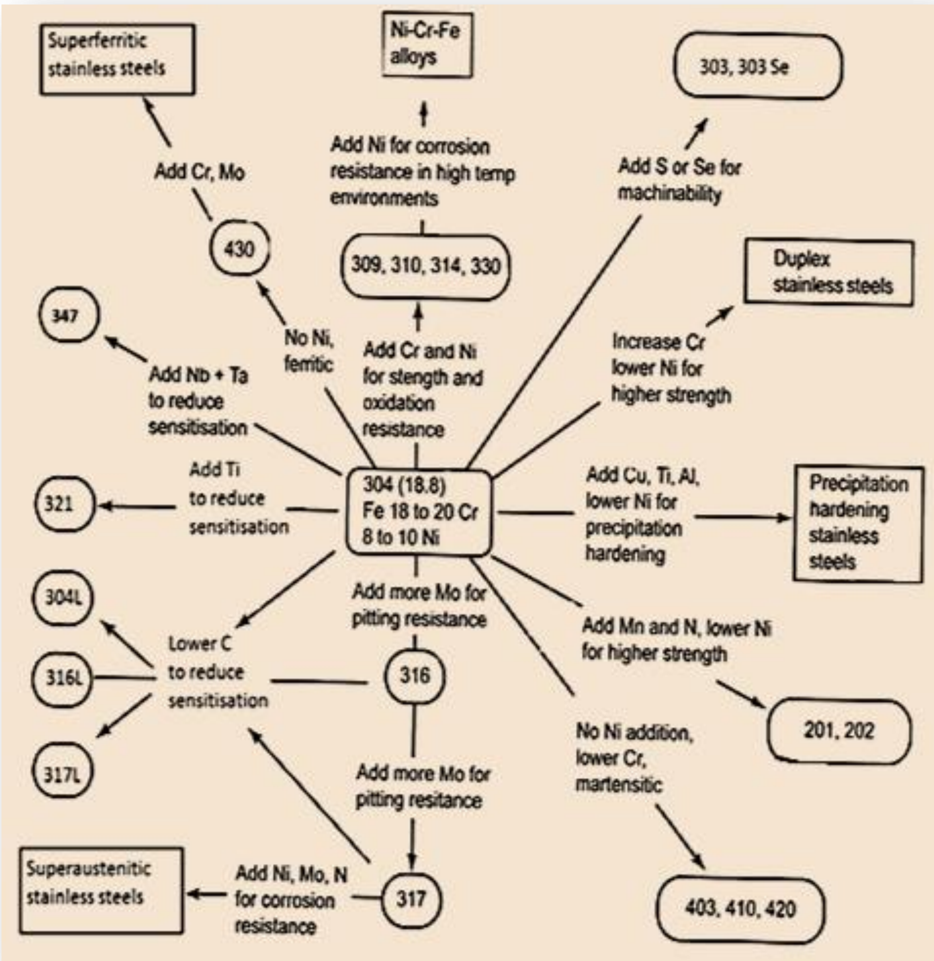
are a combination of austenitic and ferritic stainless steels in equal amounts; they contain 21 to 27 percent chromium, 1.35 to 8 percent nickel, 0.05 to 3 percent copper, and 0.05 to 5 percent molybdenum. Duplex stainless steels are stronger and more resistant to corrosion than austenitic and ferritic stainless steels, which makes them useful in storage-tank construction, chemical processing, and containers for transporting chemicals.

Precipitation-hardening stainless steel

is characterized by its strength, which stems from the addition of aluminum, copper, and niobium to the alloy in amounts less than 0.5 percent of the alloy's total mass. It is comparable to austenitic stainless steel with respect to its corrosion resistance, and it contains 15 to 17.5 percent chromium, 3 to 5 percent nickel, and 3 to 5 percent copper. Precipitation-hardening stainless steel is used in the construction of long shafts.

AISI Number	UNS Number	Composition (wt.%)	Condition	Mechanical Properties: UTS (MPa)	YS (MPa)	Ductility (%EL)	Typical Applications
				Ferritic			
409	S40900	0.08 C, 9.0 Cr, 1.0 Mn, 0.5 Ni, 0.75 Ti	Annealed	380	205	20	Automotive exhaust components, tanks for agricultural sprays
446	S44600	0.20 C, 25 Cr, 1.5 Mn	Annealed	515	275	20	Valves (high temperature), glass molds, combustion chambers
				Austenitic			
304	S30400	0.08 C, 19 Cr, 9.0 Ni, 2.0 Mn	Annealed	515	205	40	Chemical and food processing equipments, cryogenic vessels
316L	S31603	0.03 C, 17 Cr, 12 Ni, 2.5 Mo, 2.0 Mn	Annealed	485	170	40	Welding construction
				Martensitic			
410	S41000	0.15 C, 12.5 Cr, 1.0 Mn	Annealed Q & T	485 825	275 620	20 12	Rifle barrels, cutlery, jet engine parts
440A	S44002	0.70 C, 17 Cr, 0.75 Mo, 1.0 Mn	Annealed Q & T	725 1790	415 1650	20 5	Cutlery, bearings, surgical tools
				Precipitation Hardenable			
17-7PH	S17700	0.09 C, 17 Cr, 7 Ni, 1.0 Al, 1.0 Mn	Precipitation hardened	1450	1310	1 - 6	Springs, knives, pressure vessels

Table 1.1 Designations, Compositions, Mechanical Properties, and Typical Applications for Austenitic, Ferritic, and Martensitic, Stainless Steels

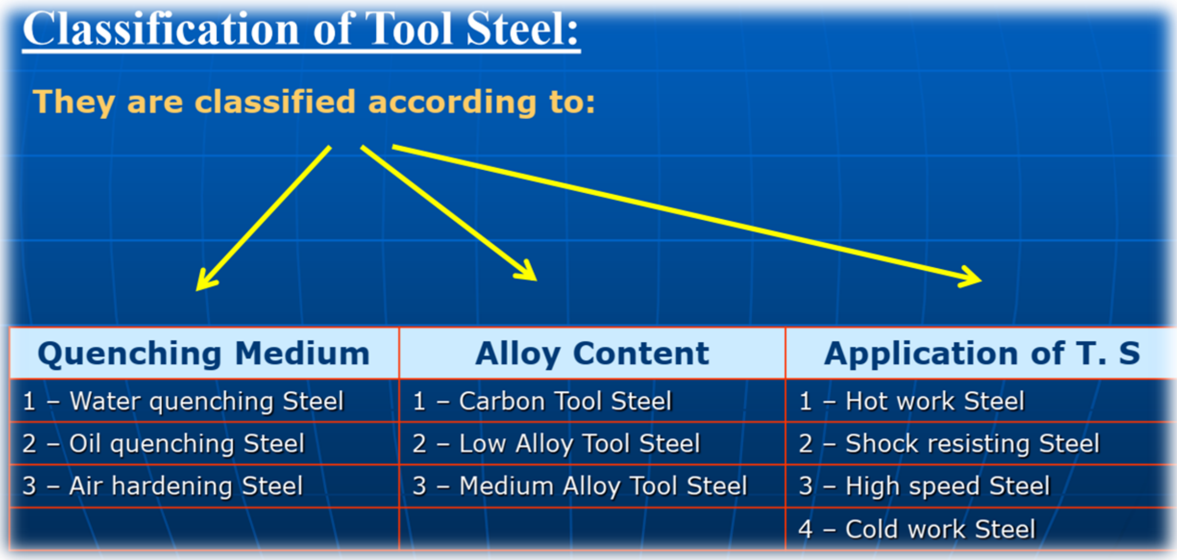


Tool steel

These are the steel used in making tools and dies which are required for cutting, shaping, forming, and blanking of materials.

These steels should have high hardness, greater abrasion or wear resistance, greater toughness, high impact strength, high thermal conductivity, low coefficient of friction.

Types of tool steel: The tool and dies steels are of the following types:-



Quenching Medium	Alloy Content	Application of T. S
1 – Water quenching Steel	1 – Carbon Tool Steel	1 – Hot work Steel
2 – Oil quenching Steel	2 – Low Alloy Tool Steel	2 – Shock resisting Steel
3 – Air hardening Steel	3 – Medium Alloy Tool Steel	3 – High speed Steel
		4 – Cold work Steel

1. Plain carbon steels:

These steels contain carbon from (0.60% to 1.4%) and are hardened either by oil or water quenching. The important advantage of these steel is that they low cost, good machinability, and high impact resistance.

The main disadvantage of carbon tool steel is poor hardenability. It needs quenching with water, brine or caustic water. Distortion and cracking tend to be large, and wear resistance and thermal strength are very low.

Therefore, carbon tool steel can only be used to make small handmade tools or woodworking tools, as well as small cold working dies with low precision, simple shape, small size and light load.

These steels are used for: keys, stamping dies, twist drills, general wood and leather cutting tools.

2. Low alloy tool steel:

These steels containing alloying elements like: vanadium, chromium, tungsten, and silicon. The presence of alloying elements refine the structure and increases the toughness and impact resistance. Compare with carbon tool steel, its hardness, toughness and wear-resistance are raise. And its hardenability and hot hardness are raised dramaticallyThe low – alloy tool steel are used for heavy duty pneumatic tools, pavement breakers. it was used to make measuring tools, molds and blade tools with big size, complex shape and high requirement of performance.
Different levels for alloy steel because of the different total amount of alloy elements. And if the alloy elements amount is less than 5%, then it is low alloy tool steel. The medium alloy tool steel is at the range of 5%-10%. And the high alloy tool steels are higher than 10%. At the present time, most of the alloy tool steel is low alloy tool steel.

3. High speed steels:

These steels are used for cutting metals at a much higher speed than ordinary carbon tool steel. The carbon steel cutting tools do not retain sharp cutting edges under heavier loads and higher speeds.

This is due to the fact that at high speed, sufficient heat may be developed during the cutting operation and causes the temperature of the cutting edge of the tool to reach a red hot. This temperature would soften the carbon tool steel and thus the tool will not work efficiently for a longer period.

The high speed steels have the valuable properly of retaining their hardness even when heated to red hot.

4. High carbon high chromium steels:

These steels are much cheaper than high speed steel (HSS), but have greater importance than HSS.

These are widely used for various types of dies like those used for drawing, coining, blanking, forming, and thread rolling.