GOVT. TOOL ROOM AND TRAINING CENTRE
KARNATAKA

REFERENCE NOTES

MATERIAL TECHNOLOGY-II

SUBJECT CODE: TDM 204

FOR
: DIPLOMA IN TOOL AND DIE MAKING
: DIPLOMA IN PRECISION MANUFACTURING

UNIT 1 – ALLOYING ELEMENTS

ALLOYING ELEMENTS

The metal is present in the greatest proportion, while other metallic or non-metallic elements present are known as alloying elements.

PURPOSE OF ALLOYING ELEMENTS:

1) To impart a fine grain size of steel.
2) To improve corrosion & fatigue resistance.
3) To improve case hardening and elasticity.
4) To improve machinability.
5) To improve hardness, toughness and tensile strength without loss of ductility.
6) To retain physical properties at higher temperature.
7) To use for special purposes.

TYPES OF ALLOY STEELS:

Manganese steel, Molybdenum steel, Nickel steel, Invar steel, &tungsten steel,

Manganese (Mn) Steels:

- Manganese 1-1.5% makes the steel strong & tough.
- Manganese 1.5% -5% steel hard and brittle.
- Manganese 11-14% & carbon 0.8-1.5 & steel become very hard, tough and non-magnetic.
- More manganese reduces strength and ductility.

Uses:

- Agricultural implements like shovels.
- Jaws of stone & ore crushes, tramway and railways points and crossing etc.

- Cover plates of lifting magnets.
- Used in rails, gears, axels, connecting rods, crank shafts, bolts, nuts staring levers, air craft fittings & gun baral's.

Molybdenum (Mo) Steels:

- Molybdenum 0.2-0.7% & carbon 0.15 – 0.7% increase tensile strength, creep strength, hardenability.

Uses:

- Rolled sections, forgings & castings.
- Molybdenum includes catalysts for the petroleum industry, ink for circuit boards, pigments and electrode.

Nickel (Ni) Steels:

Nickel 3 – 5% increase elastic limit & toughness,
Nickel 20% increase very high tensile strength,
Nickel 27% increase non-magnetic & non-corrodible.

Uses:

Long span, bridges, wrist pins, pinions, engine cams, transmission gears, propeller shafts, stud & bolts, aero plane parts, crank shafts etc.

Invar Steels:

Invar (Ni 36%)   super invar (Ni31%)

Uses:

Measuring instruments, surveyor tapes, clocks etc…

Tungsten (W) steels:

Tungsten 1.5% increase steel too hard, and retains sharp edges at higher temperature.

Uses:

Making permanent magnets, high speed cutting tools, incandescent light bulbs, excellent cutting & drilling tools, arc-welding electrodes etc…

STAINLESS STEEL (SS):

It is the rustless or corrosion resistance steel containing about 0.4% carbon, 4.5 to 18% chromium. It is hard without heat treatment & retains bright silvery white surface.

It is used for domestic purposes, surgical instruments and machine parts, nuclear plants, power generating units, pulp and paper manufacturing plants, food processing units and petrochemical industries etc.

HIGH SPEED STEELS (HSS):

- When cutting tool is used at high speed, due to the friction between the tool & job tremendous amount of heat is generated which rises the temperature of the tool tip visible red heat.
- Ordinary steels do not withstand this heat. But high speed steel have the property to withstand the heating effect without losing hardness, so called as high speed steels are of compositions that have good wear resistance & retain their hardness at higher temperature.
- The superior brand of HSS is T70W18 Cr4V1 or 18-4-1, which stands for 18% tungsten, 4% chromium % 1% vanadium.

This brand of HSS are used for machining operation on steel & non-ferrous materials, reamers, milling cutters, twist drills, taps etc.

One of the most popular grades among all HSS is designated as 18:4:1. It contains about 0.7% carbon, 18% tungsten, 4% chromium, 1% vanadium.

I.S CODIFICATION FOR STEELS:

IS designates the various grades of steels by system of codification which bears direct relationship with the important characteristics of steel such as tensile strength, chemical composition , physical and surface conditions.

According to this method a particular grade designation would be applicable to certain steel only. This type of code is followed with the idea that it will be possible to simplify reference, making and identification of the various types of steels.

According to IS method steel may be designated by a group of symbols indicating the important characteristics in the following.

- Tensile strength
- Carbon content
- Alloy content
- Sulphur and Phosphorous
- Weldability
- Surface finish
- Surface condition
- Steel quality
- Treatment

Carbon Content:

IS code considers four types of steels for designating carbon content in the steel.

i) Plain carbon steels
ii) Alloy steels
iii) Carbon tool steels
iv) Alloy tool steels

Plain Carbon Steel:

These steels are designated by letter ‘C’ followed by the average carbon content in hundredths of a percent. Thus plain carbon steel having carbon (0.50 to 0.60%) and manganese (0.75 to 0.85%) will be designated as C55.

Alloy Steels:

These are simply designated by the average carbon content in hundredths of a percent without using the prefix ‘C’. Thus an alloy steel having carbon (0.20 to 0.30%), Silicon (0.10 to 0.30%), and Manganese (1.25 to 1.75%), Chromium (0.45 to 0.55%), Nickel (1 to 2%), will be designated as 25 XXX.

Carbon Tool Steels:

These are designated by letter ‘T’ followed by the average carbon content in hundredths of a percent. Thus carbon tool steel having 0.40 to 0.50%carbon and silicon (1.25 to 1.75%) and manganese (0.55 to 0.90%) will be designates as T45.

Alloy Tool Steels:

These are designated by letter ‘T’ followed by same symbols as for alloy steels. Thus an alloy tool steel having the composition of carbon (0.50 to 0.60%), silicon (0.08 to 0.30%), manganese (0.5 to0.75%), nickel (1.05 to 1.50%), chromium (0.32% maximum) will be designated as T 55 XXX.

Alloy Content:

The alloy content in any steel is designated in the symbolic form by first specifying the average carbon content in the hundredths of a percent, followed by the chemical symbols of the significant elements in the descending order of the percentages contents, the nominal or average percentage of each alloying element being indicated by an index number just after its chemical symbol.

In case the average alloy content is up to 1% then the index number will be expressed up to 2 decimal places underlined by a bar except in cases of boron, nitrogen etc, where it will be indicated by the alloy symbol only, e.g. if chromium content by between 0.50 to 0.80%, it will be represented as Cr.65.

If the alloy content lies between 1 to 10% then the index number will be rounded to the nearest whole number (up to 0.5 being rounded down and 0.5 and over being rounded up). If considered necessary, the alloying content may be rounded off to one place of decimal digit being underlined by a bar e.g... Chromium content between 1.20 to 1.60 may be represented either as Cr.1 or Cr 1.4.

If the alloy content lies between 10 and 100% then index number will be rounded to the nearest whole number, e.g. if chromium content be between 12 and 18% then it will be represented as Cr 15.

If two or more significant alloying elements have the same alloying elements have the same alloy index, then their chemical symbols may be grouped together followed by their alloy index e.g., if a steel contains nickel between 0.90 to 1.30% and chromium between 1.20 to 1.60% then both these may be represented as NiCr 1.

On the above principles, certain examples are given below:

Nickel-Chromium-Molybdenum alloy steel with the following composition will be designated as:

50Ni3Cr1Mo30

Carbon	0.50 to 0.60%
Silicon	0.28 to 0.32%
Manganese	0.35 to 0.45%
Nickel	2.50 to 3.50%
Chromium	0.80 to 1.20%
Molybdenum	0.28 to 0.32%

Plain carbon free cutting steel with the following composition will be designated as:

35S18

Carbon	0.30 to 0.40%
Manganese	0.80 to 1.20%
Sulphur	0.12 to 0.24%
Phosphorous	0.06 to max%

Alloy tool steel having the following composition will be designated as:

T04 Cr17Ni9Ti20

Carbon	0.08 to max%
Silicon	0.30 to 1.00%
Manganese	0.40 to 1.80%
Nickel	6.00 to 12.0%
Chromium	16.0 to 18.0%
Titanium	5 times the average carbon content, minimum

Steel having the following composition will be designated as:
Steel having the following composition will be designated as:

T75W18Cr4V1

Carbon	0.70 to 0.80%

Manganese	0.28 to 0.32%
Silicon	0.19 to 0.21%
Chromium	4.00 to 4.50%
Tungsten	18.0 to 19.0%
Vanadium	1.00%

Constituent of Iron and Steel:

1. Ferrite,
2. Cementite,
3. Pearlite,
4. Bainite,
5. Martensite,
6. Austenite.

Ferrite (Fe):

The pure iron grains or crystals are called ferrite. Pure iron means carbon free iron. It cannot be hardened by cooling rapidly. Low carbon steel and wrought iron consists ferrite.

Cementite (Fe_3C):

It is carbide of iron. It is extremely hard. The hardness and brittleness of cast iron due to cementite. It is magnetic below 2600˚C. Its pressure in iron and steel increases hardness and decreases tensile strength. It is having 93.45% iron, 6.55% carbon. Tensile strength is below 360kgf/cm².

Pearlite:

It is a mixture of 87.5% ferrite and 12.5% cementite. It occurs particularly in low or medium carbon steel in the form of alternate layers. When seen in the microscope, the surface of cooling has appearance of pearl (rainbow colors).

During process of cooling at slow rate from a red heat, cementite forms a mechanical mixture with ferrite, and appears under high magnification as alternative layers of cementite and ferrite. This constituent is called pearlite. Slow cooling produce coarse pearlite and quicker cooling produce finer pearlite.

Bainite:

This is a transformation state of pearlite. This is obtained by low temperature isothermal transformation and structurally it has iron carbide dispersed in ferrite.

Bainite obtained by transformation of pearlite at higher temperature has feathery structure and is called upper bainite. Bainite obtained by low temperature transformation has got needle like or circular structure and is called lower bainite.

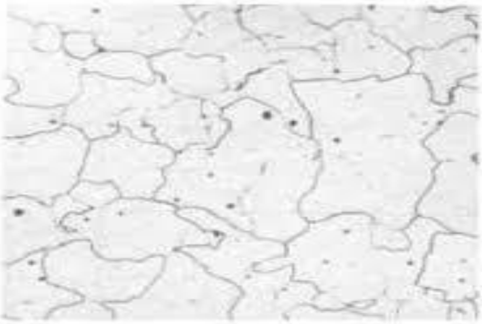
Martensite:

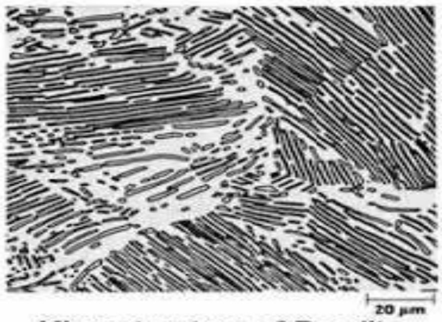
It is the chief constituent of hardened steel. It is fibrous or needle like structure. It is very hard and consists of iron with carbon in varying proportion up to 2%.

When it contains iron and 0.9% carbon it is termed as Hardnite, which corresponds in composition to that of pearlite or martensite saturate with carbon. Martensite is not as tough as austenite.

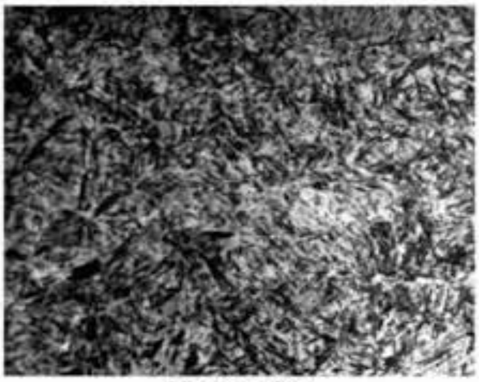
Austenite:

Austenite is the solid solution of carbon or iron carbide Fe_3C. When the carbon steel is heated, the internal constituent change until a temperature corresponding to the lower critical is reached, this is about 723˚C to 727˚C.


Microstructure of Ferrite

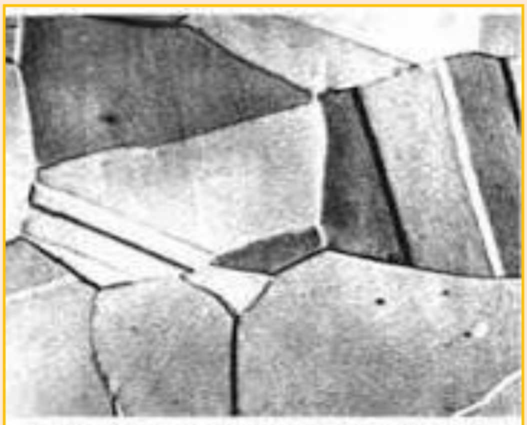


Microstructure of Pearlite


Martensite


Lower Bainite


Upper Bainite



Microstructure of Austenite

EUTECTOID STEEL:

Steel contains 0.8% carbon is called Eutectoid steel and it contains only pearlite.

HYPO EUTECTOID STEEL:

Steel which contains less than 0.8% of carbon is called Hypo eutectoid steel. And it contains pearlite and ferrite.

HYPER EUTECTOID STEEL:

Steel which contains more than 0.8% of carbon is called hyper eutectoid steel. And it contains pearlite and cementite.

Other Constituent of Steel:

1. **α-Iron (Alpha iron)**
2. **β-Iron (Beta iron)**
3. **ϒ-Iron (Gamma iron)**
4. **Δ-Iron (Delta iron)**

α-Iron (Alpha iron):

Ferrite in its normal condition is known as alpha iron or alpha ferrite. It is weak and ductile, possesses magnetic properties and is unable to dissolve carbon.

β-Iron (Beta iron):

Beta iron is ferrite in the temperature range 768˚C to 900˚C at which it possesses power of dissolving carbon. It is very hard, brittle, and non-magnetic.

ϒ-Iron (Gamma iron):

When pure iron is further heated from 900˚C to 1399˚C, which is a temperature above the upper critical temperature there, is a change in crystal structure of the iron known as gamma iron.

Δ-Iron (Delta iron):

Pure iron is known as delta

Critical Range:

The temperature range during which transformation of pearlite to austenite takes place is called critical range.

Higher Critical Temperature:

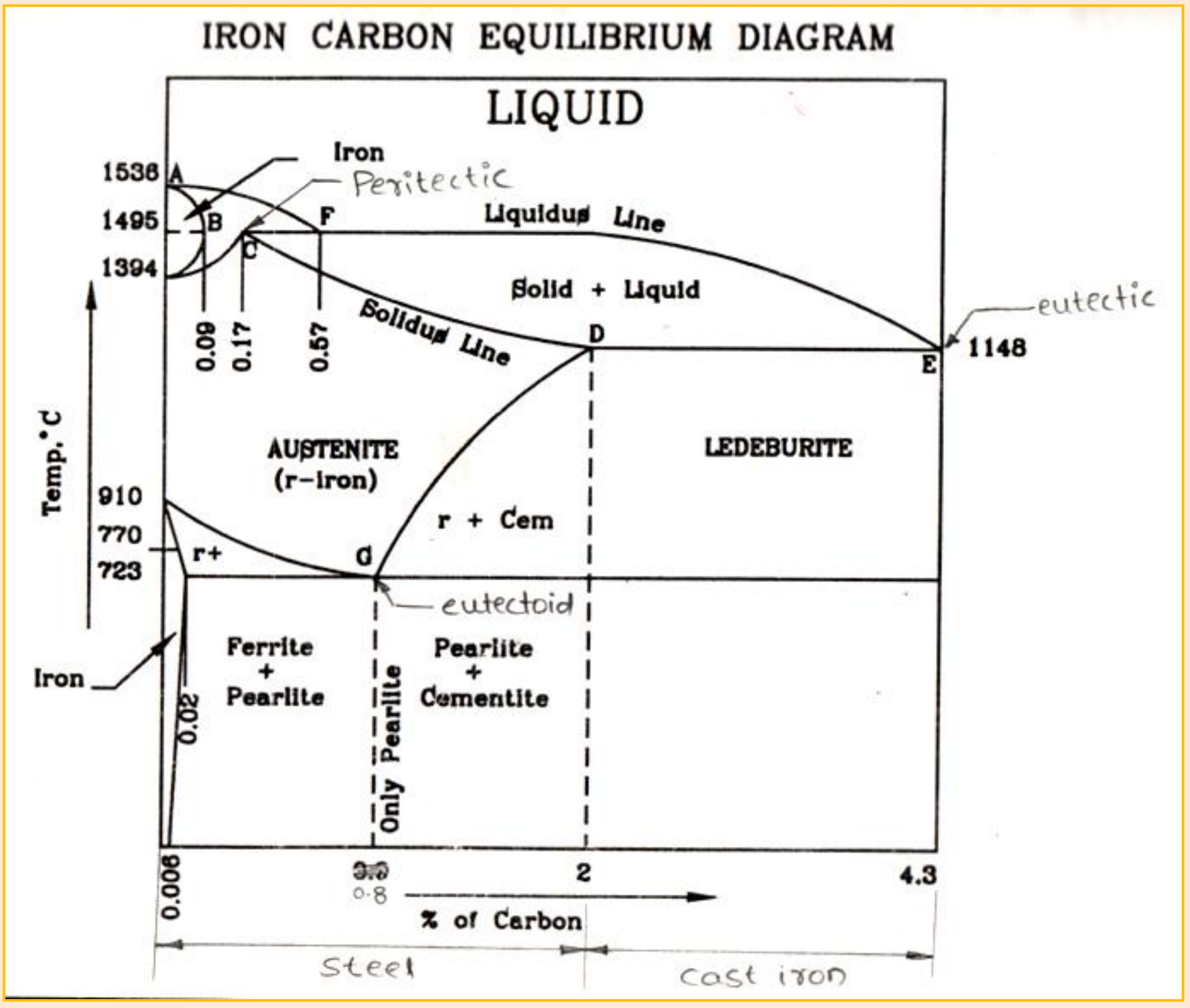
The temperature at which the transformation of pearlite to austenite ends during heating is called higher critical temperature.

Lower critical temperature:

The temperature at which the transformation of pearlite to austenite begins during heating is called higher critical temperature.

UNIT 2 – IRON-CARBON EQUILIBRIUM DIAGRAM

IRON – CARBON EQUILIBRIUM DIAGRAM



1. Ferrite is pure iron containing about 0.006% carbon at room temperature. It contains a maximum of 0.02% carbon at 723°C. It is also called as Alpha iron. Ferrite is strongly magnetic at room temperature & loses its magnetic property at 770°C.

It exhibits a body centered cubic structure up to 910°C & changes to austenite which has Face centered cubic structure.

2. Austenite is called Gama iron. It is a solid solution of carbon in iron. It can contain a maximum of 2% carbon at 1148°C. it is also soft & ductile but stronger & more ductile than ferrite. It is non-magnetic.

3. Delta iron exists at temperature as high as 1394°C to 1536°C. It can contain a maximum of 0.09% carbon at 1495°C. Because of its existence at such high temperatures, the delta iron is only of theoretical importance.

4. Liquidus line: when melting has started taking place, if the steel is further heated to a temperature which intersects the line AFE, the process of melting comes to an end. This line is called the 'liquidus line'.

5. In the region above the liquidus line, there will be only liquid and I the region below the solidus line, there will be only solid.

6. **Eutectoid reaction:**

When the austenite containing 0.8% carbon is cooled to 723°C, the austenite is converted to pearlite. This reaction is called 'Eutectoid reaction'. The point G, where the eutectoid reaction takes place is called 'eutectoid point and the temperature 723°C is called eutectoid temperature.

Austenite ⟶ 723°C (0.8% C) ⟶ Pearlite

7. **Eutectic reaction:**

When liquid alloy containing 4.3% carbon is cooled to 1148°C, the liquid gets converted into ledeburite. This reaction is called 'Eutectic reaction'. The point E, where the eutectic reaction takes place is called 'eutectic point and the temperature 1148°C is called eutectic temperature.

Liquid alloy ⟶ 1148°C (4.3% C) ⟶ Ledeburite

8. **Peritectic reaction:**

UNIT 1 – ALLOYING ELEMENTS

When a mixture of delta iron and liquid alloy containing 0.17% carbon is cooled to 1495°C, the liquid gets converted to austenite. This reaction is called 'peritectic reaction'. The point C, where the peritectic reaction takes place is called 'peritectic point and the temperature 1495°C is called peritectic temperature.

Delta iron+ Liquid alloy $\longrightarrow$ 1495°C (0.17% C) $\longrightarrow$ Austenite

ALLOYING ELEMENTS

The metal is present in the greatest proportion, while other metallic or non-metallic elements present are known as alloying elements.

PURPOSE OF ALLOYING ELEMENTS:

8) To impart a fine grain size of steel.
9) To improve corrosion & fatigue resistance.
10) To improve case hardening and elasticity.
11) To improve machinability.
12) To improve hardness, toughness and tensile strength without loss of ductility.
13) To retain physical properties at higher temperature.
14) To use for special purposes.

TYPES OF ALLOY STEELS:

Manganese steel, Molybdenum steel, Nickel steel, Invar steel, &tungsten steel,

Manganese (Mn) Steels:

- Manganese 1-1.5% makes the steel strong & tough.
- Manganese 1.5% -5% steel hard and brittle.
- Manganese 11-14% & carbon 0.8-1.5 & steel become very hard, tough and non-magnetic.
- More manganese reduces strength and ductility.

Uses:

- Agricultural implements like shovels.
- Jaws of stone & ore crushes, tramway and railways points and crossing etc.
- Cover plates of lifting magnets.
- Used in rails, gears, axels, connecting rods, crank shafts, bolts, nuts staring levers, air craft fittings & gun baral's.

Molybdenum (Mo) Steels:

- Molybdenum 0.2-0.7% & carbon 0.15 – 0.7% increase tensile strength, creep strength, hardenability.

Uses:

- Rolled sections, forgings & castings.
- Molybdenum includes catalysts for the petroleum industry, ink for circuit boards, pigments and electrode.

Nickel (Ni) Steels:

Nickel 3 – 5% increase elastic limit & toughness,
Nickel 20% increase very high tensile strength,
Nickel 27% increase non-magnetic & non-corrodible.

Uses:
Long span, bridges, wrist pins, pinions, engine cams, transmission gears, propeller shafts, stud & bolts, aero plane parts, crank shafts etc.

Invar Steels:

Invar (Ni 36%) super invar (Ni31%)

Uses:
Measuring instruments, surveyor tapes, clocks etc…

Tungsten (W) steels:

Tungsten 1.5% increase steel too hard, and retains sharp edges at higher temperature.

Uses:
Making permanent magnets, high speed cutting tools, incandescent light bulbs, excellent cutting & drilling tools, arc-welding electrodes etc…

STAINLESS STEEL (SS):

It is the rustless or corrosion resistance steel containing about 0.4% carbon, 4.5 to 18% chromium. It is hard without heat treatment & retains bright silvery white surface.

It is used for domestic purposes, surgical instruments and machine parts, nuclear plants, power generating units, pulp and paper manufacturing plants, food processing units and petrochemical industries etc.

HIGH SPEED STEELS (HSS):

- When cutting tool is used at high speed, due to the friction between the tool & job tremendous amount of heat is generated which rises the temperature of the tool tip visible red heat.
- Ordinary steels do not withstand this heat. But high speed steel have the property to withstand the heating effect without losing hardness, so called as high speed steels are of compositions that have good wear resistance & retain their hardness at higher temperature.
- The superior brand of HSS is T70W18 Cr4V1 or 18-4-1, which stands for 18% tungsten, 4% chromium % 1% vanadium.

This brand of HSS are used for machining operation on steel & non-ferrous materials, reamers, milling cutters, twist drills, taps etc.

One of the most popular grades among all HSS is designated as 18:4:1. It contains about 0.7% carbon, 18% tungsten, 4% chromium, 1% vanadium.

I.S CODIFICATION FOR STEELS:

IS designates the various grades of steels by system of codification which bears direct relationship with the important characteristics of steel such as tensile strength, chemical composition , physical and surface conditions.

According to this method a particular grade designation would be applicable to certain steel only. This type of code is followed with the idea that it will be possible to simplify reference, making and identification of the various types of steels.

According to IS method steel may be designated by a group of symbols indicating the important characteristics in the following.

- Tensile strength
- Carbon content
- Alloy content
- Sulphur and Phosphorous
- Weldability
- Surface finish
- Surface condition

- Steel quality
- Treatment

Carbon Content:

IS code considers four types of steels for designating carbon content in the steel.

v) Plain carbon steels
vi) Alloy steels
vii) Carbon tool steels
viii) Alloy tool steels

Plain Carbon Steel:

These steels are designated by letter 'C' followed by the average carbon content in hundredths of a percent. Thus plain carbon steel having carbon (0.50 to 0.60%) and manganese (0.75 to 0.85%) will be designated as C55.

Alloy Steels:

These are simply designated by the average carbon content in hundredths of a percent without using the prefix 'C'. Thus an alloy steel having carbon (0.20 to 0.30%), Silicon (0.10 to 0.30%), and Manganese (1.25 to 1.75%), Chromium (0.45 to 0.55%), Nickel (1 to 2%), will be designated as 25 XXX.

Carbon Tool Steels:

These are designated by letter 'T' followed by the average carbon content in hundredths of a percent. Thus carbon tool steel having 0.40 to 0.50%carbon and silicon (1.25 to 1.75%) and manganese (0.55 to 0.90%) will be designates as T45.

Alloy Tool Steels:

These are designated by letter 'T' followed by same symbols as for alloy steels. Thus an alloy tool steel having the composition of carbon (0.50 to

0.60%), silicon (0.08 to 0.30%), manganese (0.5 to0.75%), nickel (1.05 to 1.50%), chromium (0.32% maximum) will be designated as T 55 XXX.

Alloy Content:

The alloy content in any steel is designated in the symbolic form by first specifying the average carbon content in the hundredths of a percent, followed by the chemical symbols of the significant elements in the descending order of the percentages contents, the nominal or average percentage of each alloying element being indicated by an index number just after its chemical symbol.

In case the average alloy content is up to 1% then the index number will be expressed up to 2 decimal places underlined by a bar except in cases of boron, nitrogen etc, where it will be indicated by the alloy symbol only, e.g. if chromium content by between 0.50 to 0.80%, it will be represented as Cr.65.

If the alloy content lies between 1 to 10% then the index number will be rounded to the nearest whole number (up to 0.5 being rounded down and 0.5 and over being rounded up). If considered necessary, the alloying content may be rounded off to one place of decimal digit being underlined by a bar e.g... Chromium content between 1.20 to 1.60 may be represented either as Cr.1 or Cr 1.4.

If the alloy content lies between 10 and 100% then index number will be rounded to the nearest whole number, e.g. if chromium content be between 12 and 18% then it will be represented as Cr 15.

If two or more significant alloying elements have the same alloying elements have the same alloy index, then their chemical symbols may be grouped together followed by their alloy index e.g., if a steel contains nickel between 0.90 to 1.30% and chromium between 1.20 to 1.60% then both these may be represented as NiCr 1.

On the above principles, certain examples are given below:

Nickel-Chromium-Molybdenum alloy steel with the following composition will be designated as:

50Ni3Cr1Mo30

Carbon	0.50 to 0.60%
Silicon	0.28 to 0.32%

Manganese	0.35 to 0.45%
Nickel	2.50 to 3.50%
Chromium	0.80 to 1.20%
Molybdenum	0.28 to 0.32%

Plain carbon free cutting steel with the following composition will be designated as:

35S18

Carbon	0.30 to 0.40%
Manganese	0.80 to 1.20%
Sulphur	0.12 to 0.24%
Phosphorous	0.06 to max%

Alloy tool steel having the following composition will be designated as:

T04 Cr17Ni9Ti20

Carbon	0.08 to max%
Silicon	0.30 to 1.00%
Manganese	0.40 to 1.80%
Nickel	6.00 to 12.0%
Chromium	16.0 to 18.0%
Titanium	5 times the average carbon content, minimum

Steel having the following composition will be designated as:
Steel having the following composition will be designated as:

T75W18Cr4V1

Carbon	0.70 to 0.80%
Manganese	0.28 to 0.32%
Silicon	0.19 to 0.21%
Chromium	4.00 to 4.50%
Tungsten	18.0 to 19.0%
Vanadium	1.00%

Constituent of Iron and Steel:

7. Ferrite,
8. Cementite,
9. Pearlite,

10. Bainite,
11. Martensite,
12. Austenite.

Ferrite (Fe):

The pure iron grains or crystals are called ferrite. Pure iron means carbon free iron. It cannot be hardened by cooling rapidly. Low carbon steel and wrought iron consists ferrite.

Cementite (Fe_3C):

It is carbide of iron. It is extremely hard. The hardness and brittleness of cast iron due to cementite. It is magnetic below 2600˚C. Its pressure in iron and steel increases hardness and decreases tensile strength. It is having 93.45% iron, 6.55% carbon. Tensile strength is below 360kgf/cm².

Pearlite:

It is a mixture of 87.5% ferrite and 12.5% cementite. It occurs particularly in low or medium carbon steel in the form of alternate layers. When seen in the microscope, the surface of cooling has appearance of pearl (rainbow colors).

During process of cooling at slow rate from a red heat, cementite forms a mechanical mixture with ferrite, and appears under high magnification as alternative layers of cementite and ferrite. This constituent is called pearlite. Slow cooling produce coarse pearlite and quicker cooling produce finer pearlite.

Bainite:

This is a transformation state of pearlite. This is obtained by low temperature isothermal transformation and structurally it has iron carbide dispersed in ferrite.

Bainite obtained by transformation of pearlite at higher temperature has feathery structure and is called upper bainite. Bainite obtained by low temperature transformation has got needle like or circular structure and is called lower bainite.

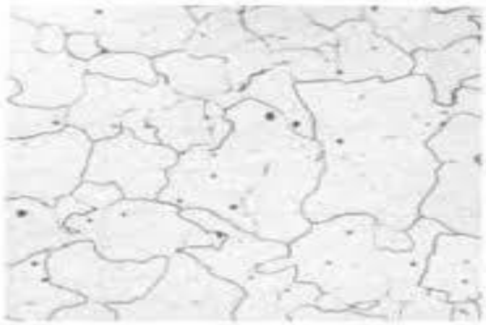
Martensite:

It is the chief constituent of hardened steel. It is fibrous or needle like structure. It is very hard and consists of iron with carbon in varying proportion up to 2%.

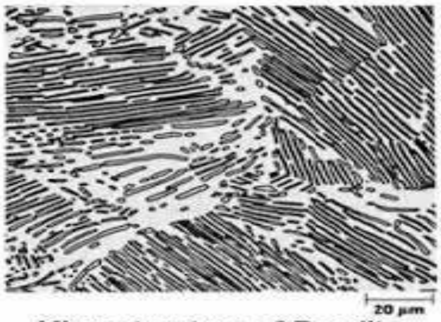
When it contains iron and 0.9% carbon it is termed as Hardnite, which corresponds in composition to that of pearlite or martensite saturate with carbon. Martensite is not as tough as austenite.

Austenite:

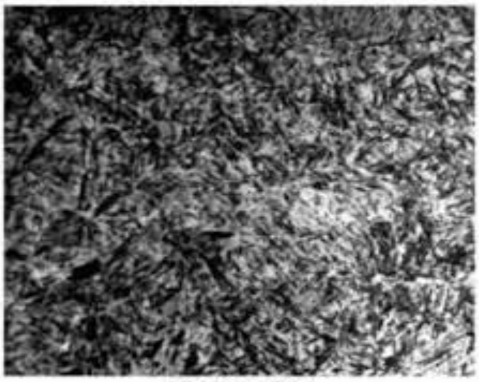
Austenite is the solid solution of carbon or iron carbide Fe_3C. When the carbon steel is heated, the internal constituent change until a temperature corresponding to the lower critical is reached, this is about 723˚C to 727˚C.



Microstructure of Ferrite



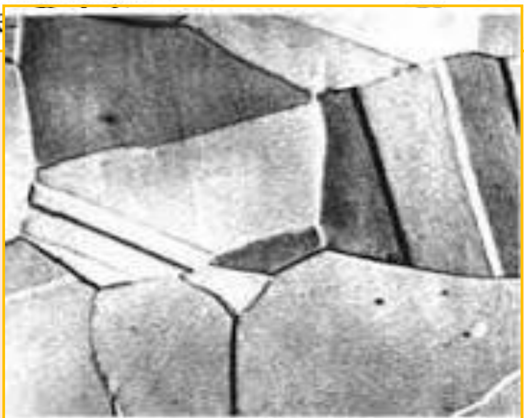
Microstructure of Pearlite



Martensite

Lowe

Bainite



Microstructure of Austenite

EUTECTOID STEEL:

Steel contains 0.8% carbon is called Eutectoid steel and it contains only pearlite.

HYPO EUTECTOID STEEL:

Steel which contains less than 0.8% of carbon is called Hypo eutectoid steel. And it contains pearlite and ferrite.

HYPER EUTECTOID STEEL:

Steel which contains more than 0.8% of carbon is called hyper eutectoid steel. And it contains pearlite and cementite.

Other Constituent of Steel:

5. **α-Iron (Alpha iron)**
6. **β-Iron (Beta iron)**
7. **ϒ-Iron (Gamma iron)**
8. **Δ-Iron (Delta iron)**

α-Iron (Alpha iron):

Ferrite in its normal condition is known as alpha iron or alpha ferrite. It is weak and ductile, possesses magnetic properties and is unable to dissolve carbon.

β-Iron (Beta iron):

Beta iron is ferrite in the temperature range 768˚C to 900˚C at which it possesses power of dissolving carbon. It is very hard, brittle, and non-magnetic.

ϒ-Iron (Gamma iron):

When pure iron is further heated from 900˚C to 1399˚C, which is a temperature above the upper critical temperature there, is a change in crystal structure of the iron known as gamma iron.

Δ-Iron (Delta iron):

Pure iron is known as delta

Critical Range:

The temperature range during which transformation of pearlite to austenite takes place is called critical range.

Higher Critical Temperature:

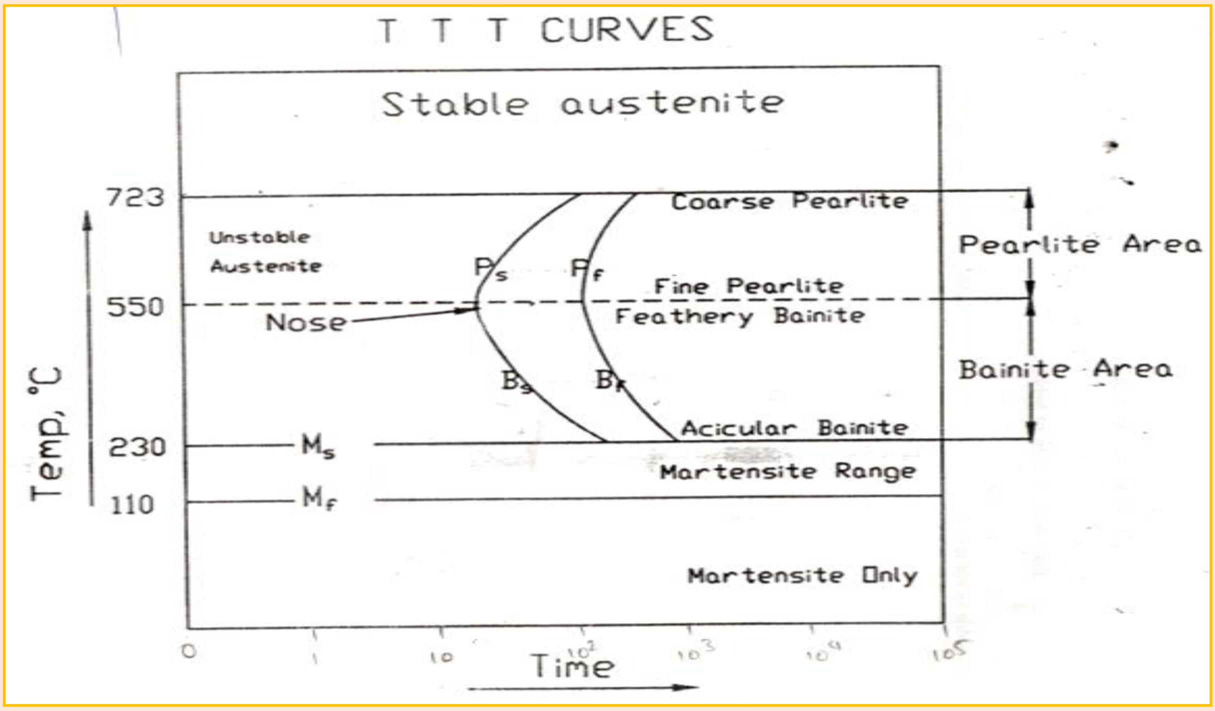
The temperature at which the transformation of pearlite to austenite ends during heating is called higher critical temperature.

Lower critical temperature:

The temperature at which the transformation of pearlite to austenite begins during heating is called higher critical temperature.

UNIT 4 – TTT CURVES AND QUENCHING

TIME TEMPERATURE TRASFORMATION



1. The TTT curves are drawn when the steel which is heated to the austenite phase is cooled to a temperature less than 723°C and the behavior of steel is observed by maintaining constant temperature.

   Since the TTT curves are drawn at constant temperature, they are also called Isothermal curves.

2. At any temperature less than 723°C, the austenite is unstable. But when the steel is cooled to a temperature less than 723°C, the unstable austenite remains stable for a period of time. This period is called **Incubation period** and it depends on the temperature.

3. The important part of the curve is called the **NOSE**. It occurs at 550°C. The nose divides the curve into two parts.

4. The martensite transformation takes place in the range from 230°C-110°C

   Martensite start --------- 110°C
   Martensite finish --------- 230°C

5. The bainite transformation takes place in the range from 230°C-550°C

   Acicular Bainite --------- 230°C
   Feathery Bainite --------- 550°C

6. The pearlite transformation takes place in the range from 550°C-723°C

   Fine Pearlite ----------- 550°C
   Coarse Pearlite ----------- 723°C

UNIT 5 – DEFECTS IN HEAT TREATMENT

DEFECTS IN HEATTREATMENT

Heat treatment is a heating and cooling process by which the microstructure and mechanical properties of metals and alloys are improved.

When metal fails to achieve the desired properties and the process is said to be defective this may be due to,

1. Unstable chemical composition of alloying steel
2. Wrong selection of the material
3. Improve design of a tool and a machined component
4. Inherent material

The most common defect observed in heat treatment steels are:

1. Low hardness and strength after hardening.
2. Soft spots.
3. Oxidation and decarburization.
4. Overheating and burning.
5. Formation of cracks.
6. Distortion and warpage.

QUENCH CRACKS

Sometimes cracks are formed in steel as a result of stresses produced during transformation of austenite to martensite. The cracks may be small of large often these appear after a steel sample has been quenched.

Transformation of austenite to martensite is accompanied by increase in value. As a result compressive stress is induced and cracks appear steel component with quench crack cannot be used. It is a scrap.

Causes: -
Internal stresses, non-uniform cooling,

Remedies: -
Cooling slowly in martensitic range by using oil as the quenching media,

DISTORTION

Distortion refers to change in the size & shape of heat treated component due to thermal & structural stresses.

- Design abrupt changes,
- Sharp corners and thin walls should be avoided in the component,
- Composition proper selection of the steel.

Remedies:-
- Uniform microstructure in the component and uniform temperature in the furnace should be maintained.
- Rough machining to dimensions accounts for size distortion during heat treatment.

WARPING

Warping effects to asymmetrical deformation of component occurs during quenching.

Causes:-

- Change in volume in heating or cooling
- Non-uniform heating or cooling of component
- Internal stresses in the component before heat treatment

Remedies:-

- Using alloy steels which are only slightly deformed by quenching.
- Cooling slowly in martensitic range.
- Applying surface hardening where ever possible.
- Quenching as uniformly as possible.

UNIT 6 – SURFACE HARDENING OF STEEL

- Keeping component in proper position in quenching bath.

SURFACE HARDENING OF STEEL

In direct or through hardening, the entire part from the surface to the centre becomes hard and wear resistant. Although a high hardness is obtained throughout the cross section of the material the impact strength of the metal becomes lower.

This impact strength can be increased by tempering at a high temperature. This high temperature tempering reduces hardness. Also in many situations, the entire cross section of the material need not be hard and wear resistant. It will be sufficient, if only the surface is hard and wear resistant whereas the core remains soft and tough. This can be achieved by a process called surface treatment.

Definition:

A process of hardening a ferrous material in such a way that the surface layer or case is harder than the remaining material or core

Methods:

1. By changing the structure at the surface
2. By changing the chemical composition at the surface

Need For Surface Treatment

1. The low carbon steels or mild steels contain only up to 0.3% carbon, they cannot be hardened as the amount of martensite produced is very small. Therefore, low carbon steels are always surface treated.
2. In actual practice, the material never stressed uniformly throughout the cross section. The stress is maximum at the case and minimum at the core. In such application, surface treatment parts can be conveniently used.
3. Moreover, the core should be relatively soft and tough to support the harder core. Otherwise, if cracks appear on the surface, they propagate very easily

towards the core. Therefore, in application where the functional requirements of a material are not affected by a soft and tough core with hard and wear resistant case, surface treatment can be done.

Difference between Surface Hardening and Case Hardening

Sl No.	Surface Hardening	Case Hardening
01	The chemical composition at the surface remains unchanged.	The chemical composition at the surface changes due to addition of carbon or nitrogen.
02	It is applicable only two harden able ranges of steels, i.e., medium and high carbon steels.	It is applicable only to non-harden able range of steels, i.e., low carbon steels
03	It is comparatively faster.	It is comparatively slower.
04	Examples are flame and induction hardening.	Examples are carburizing, cyaniding and nitriding.

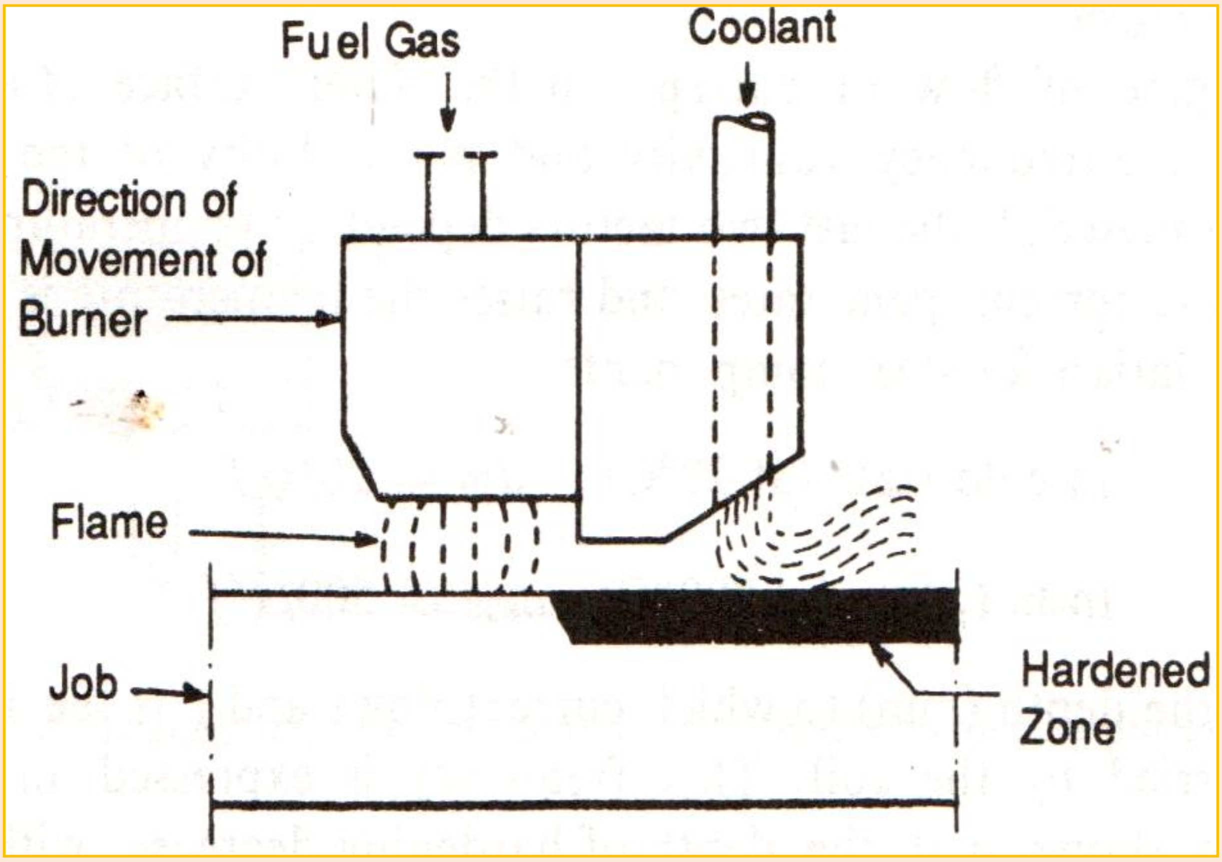
SURFACE HARDENING:

- Steel with a definite % of carbon is soft when ferrite and pearlite are present and becomes hard when martensite is present.
- By surface hardening it possible to have steel with hard martensite at the case and soft ferrite and pearlite at the core. For this to be possible the following two conditions must be satisfied.
  1. The steel should be heated in such a way that the austenite from only at case and negligible pearlite to austenite transformation takes place at the centre.
  2. After obtain austenite only at the case the steel should be cooled rapidly so that martensite forms only at the case.

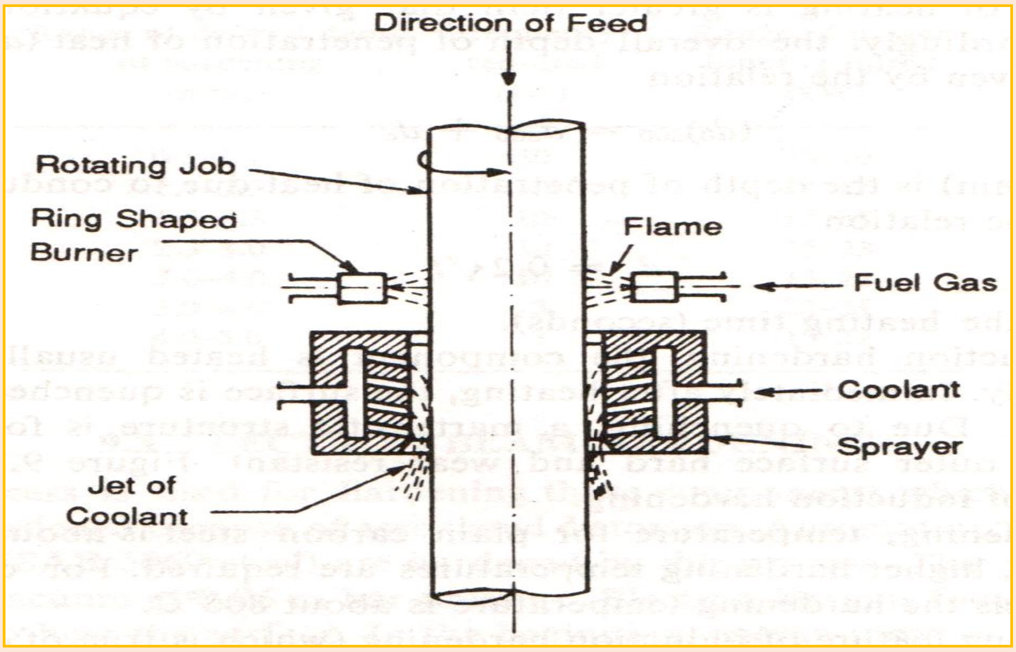
The Two Methods of Surface Hardening commonly used:

1. **Flame Hardening**
2. **Induction Hardening**

PROGRESSIVE FLAME HARDENING



PROGRESSIVE SPIN HARDENING



FLAME HARDENING

1. Heating the surface layer of harden able steel rapidly above the critical range by means of high temperature of flame.
2. Quenching is to produce martensite.
3. The flame is generally oxy-acetylene flame which produces 3000°C heat.
4. The flame temperature is more than melting temperature of steel; either the flame torch or the work piece should be continuously moving to prevent melting the work piece.
5. The heating should be immediately followed by quenching.
6. Flame hardening usually applicable for steel with 0.3 to 0.6% carbon.
7. This process depends entirely on the skill of operator in selecting the distance between the gas flame and work piece.

   Examples: crank shaft, axel, and large gear, cam, bending roller or any other complicated cross section.

Advantages of Flame Hardening:

1. Depth of hardening can be easily controlled
2. Less distortion of the material
3. Oxidation is minimum
4. Loss of carbon is also minimum

5. Clean working environments can be maintained
6. Low energy consumption
7. High output rate
8. Only light machining is required after this process
9. These products can be used directly without any additional processes

Disadvantages of Flame Hardening:

1. Lot of care is required while tempering
2. High investment cost

There are four different methods which are used in general for Flame Hardening:

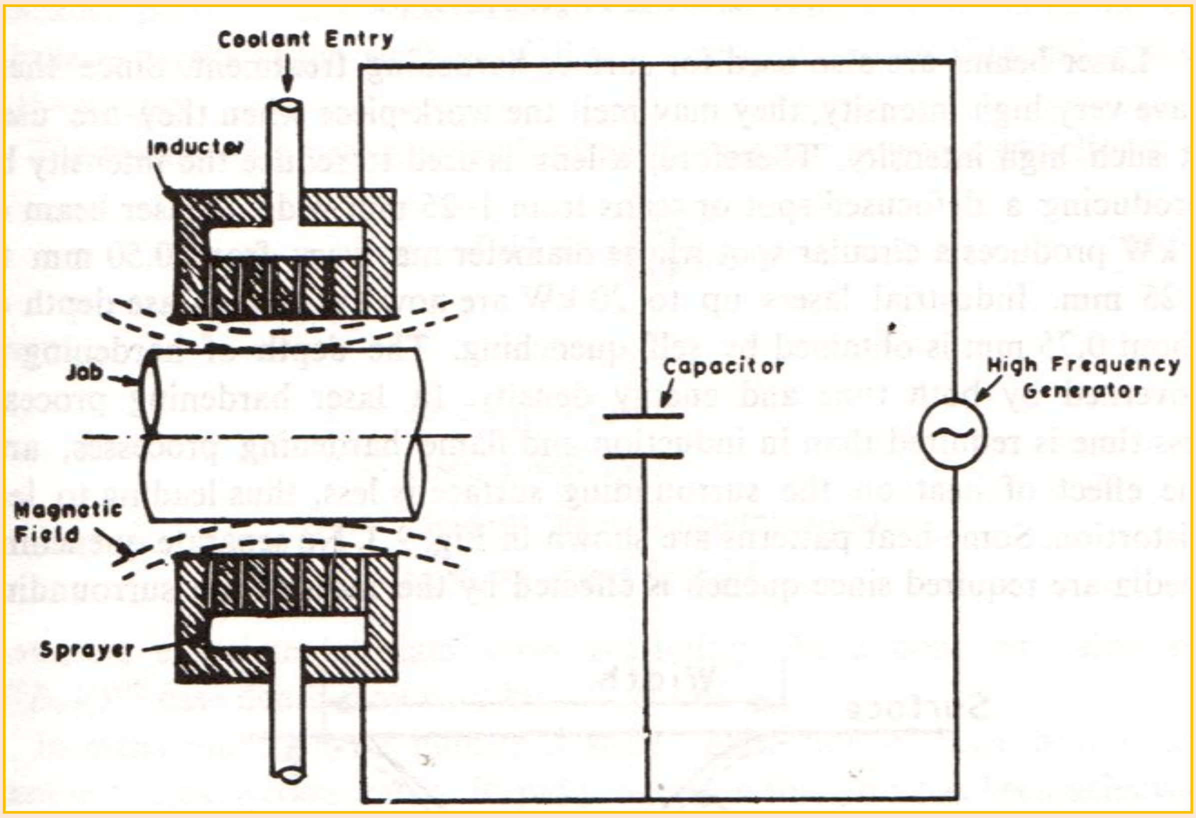
1. **Stationary:**
   Both burner and work piece are stationary.

2. **Progressive:**
   Hardening is carried out by using a burner combined with a water spray, the burner moves over the large stationary work piece.

3. **Spinning:**
   The work piece is rotated, while the burner remains stationary. After heating the flame is removed and quenching is carried out by a water jet.

4. **Progressive Spinning:**
   The burner moves over a rotating work piece and rapid quenching is carried out after heating.

INDUCTION HARDENING



1. In this process an alternating current of high frequency is passed through an inductor coil which sets up a magnetic field.
2. The heat from the coil gets induced in to the surface of the work piece and therefore the steel gets heated.
3. The component is held stationary in the induction coil and the entire surface is heated simultaneously.
4. The temperature rises above the critical range austenitic phase in few seconds.
5. The surface is quenched by jet of water which pass through the holes in the induction coil.
6. The case depth can be controlled by properly controlling the frequency of the current and duration of heating.
7. Higher case depth is obtained at lower frequencies and lower frequencies and lower duration of heating.
8. Induction hardening is suitable for steels with carbon percentage up to 0.3% to 0.7%
9. Ex: pistons and crank shafts.

Advantages of Induction Hardening:

1. Fast heating rates
2. No time wastage
3. No scaling
4. No decarburization
5. Less distortion as only the surface gets heated
6. Depth of hardening can be very easily maintained
7. Clean working environment can be maintained
8. Low energy consumption
9. High output rate

Disadvantages of Flame Hardening:

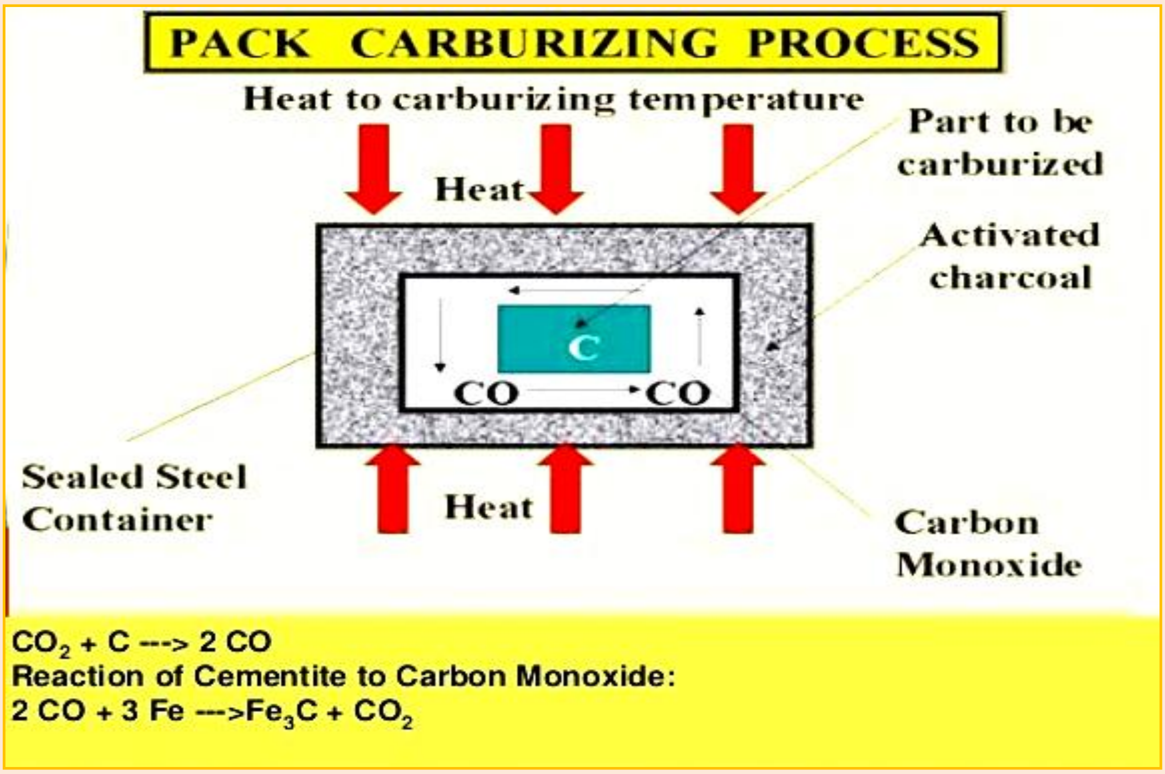
1. High cost and irregular shapes cannot be hardened easily by this process

CARBURIZING

It is the method of heat treatment in which carbon content on the surface of the material is increased. It is carried out on low carbon steels which contain from 0.10% to 0.25% carbon and are known as carburizing steels.

- Carburizing is carried out in the temperature range 900°C to 930°C and the surface layer is enriched with carbon up to 0.7% to 0.9%
- In this process, carbon is diffused into steel by heating above the transformation temperature and holding the steel in contact with a carbonaceous material which may be a solid medium, liquid or a gas.
- Carbon is absorbed in solid solution in austenite.
- The solubility of carbon is more in austenitic state than in ferritic sate, fully austenitic state is essential for carburizing.
- The surface hardness depends on the relationship of hardness with carbon content which differs slightly for different grades of steels.

PACK CARBURIZING (PACK OR SOLID)



1. It is the oldest method of carburizing steel components.
2. In this process, steel components to be heat treated are packed with 80% granular coal and 20%. $BaCO_3$ as energizer in heat resistant boxes.
3. Heated at 930°C in electric chamber furnace for a specific period of time which depends on the case depth required.
4. Such a high temperature in furnace helps in absorption of carbon depth at the outer layer.
5. Carburizing time varies from 6 to 8Hrs, and case depth obtained varies from 1mm to 2mm.
6. In this process depend on the quality of coal.
7. There is some elements of uncertainty
8. Temperature and case depth control is less than in liquid and gas carburizing

CYNIDING

1. In this process, the parts to be heat treated are immersed in a liquid bath at 800 to 960°C of NaCN with the concentration varying between 25% and 90%.
2. Carbon and nitrogen so formed in atomic from diffuse into the steel and give thin wear resistant layer of the carbonitride.

3. This process requires 30-90minutes for completion.
4. For obtaining case depth from 0.5mm to 2mm, the process is carried out at higher temperature 950°C in a bath containing 8%NaCN, 82%$BaCl_2$ and 10%NaCl.
5. This process takes 1.5 to 6hours for completion of case depth from 0.13mm to 0.35mm.
6. After cyaniding, the pieces are taken out and are quenched in water or oil for thick sections mineral oil is preferred for quenching.
7. The final operation is lower temperature tempering, the case has a hardness of 850VHN.
8. This process is less time consuming and distortion of pieces is less.
9. Because of the high heat transfer coefficient in liquid bath and uniform bath temperature.
10. This process is not suitable for hardening those parts which are subjected to shock, fatigue and impact.
11. Because nitrogen addition has adverse effect on such properties of steels.

NITRIDING

1. Nitriding is most effective for those alloy steels which contain stable nitride forming elements such as aluminium, chromium, molybdenum, vanadium and tungsten.
2. Nitriding is carried out in a ferritic region below 590°C. So there is no phase change after nitriding.
3. Before nitriding, proper heat treatment should be given to steel components to develop bainitic structure, which increases the strength and toughness of the core.
4. All machining and grinding operations are finished before nitriding.
5. Anhydrous ammonia gas is passed into the furnace at about 550°C, where it dissociates into nascent nitrogen and hydrogen.
6. The treatment time varies from 21 hours to 100hours; it depends on the desired case depth and size of the steel parts.

UNIT 7 – HARDNESS TESTING METHODS

7. After nitriding, the steel part is allowed to cool in furnace itself in the presence of ammonia.
8. The furnace container is made of heat resisting alloy steel.
9. The time required for a case depth of 0.5mm is about 100hours.
10. The hardness is achieved at the surface of steel varies from 900VHN to 1100VHN.
11. The hard layer so formed imparts good wear resistance, hot hardness and corrosion resistance.

HARDNESS TESTING METHODS

Hardness is a mechanical property of a metal. It is defined as the resistance to penetration by other materials. Hardness is an indication of the Yield strength of the metal. It is a non-destructive type of testing.

In practice, the following two types of tests are used for the hardness testing.

1. Indentation or Penetration method.

2. Rebound method.
3.

INDENTATION METHOD:

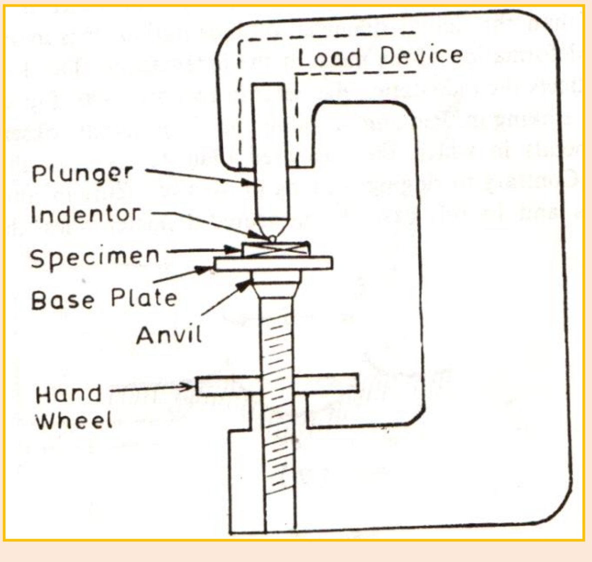
These methods are based on the principal of forcing a hard metal called Indent or against a polished surface of the metal to be tested under a fixed load. The diameter or the depth of indentation produced by the indentor on the metal is an indication of the hardness of the metal.

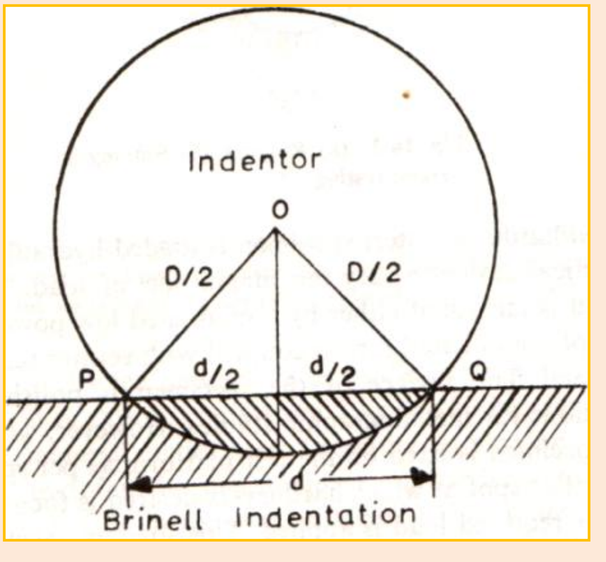
The hardness is inversely proportional to the depth of penetration or indentation. These methods give the actual value of the hardness.

The following are the different methods of hardness testing using indentation principle.

1) Brinell hardness test
2) Rockwell hardness test
3) Vickers hardness test

BRINELL HARDNESS TEST





1. In this test, a hardened steel ball of diameter D is pressed in to the flat polished surface of the material to be inspected under a fixed load P.
2. The load applied depends on the diameter of the indentor. The diameter of the indentor and the load depends on the material to be tested and its thickness.
3. Lesser ball diameter and loads should be used for thinner jobs. The hardness is determined by the diameter of indentation.
4. In practice, the diameter of indentation is measured using a Microscope.
5. The mathematical formula for BHN is given by

Metal Hardness Formula

$$BHN = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

$BHN - Brinell\ Hardness\ Number$
$in\ kg/mm^2$
$P - load\ in\ kgf$
$D - steel\ ball\ diameter\ in\ mm$
$d - depression\ diameter\ in\ mm$

6. The Brinell test is usually used for Cast iron and Steel.
7. This test produces very large indentation and therefore cannot be used for very thin sheets, plated metals and surface hardened steels.
8. Also, it cannot be used near the edges of the jobs. The standard combination of the load and diameter of the indentor used in the Brinell test are as follows.

Sl No.	Diameter of indentor, in mm.	Load on Indentor, in Kg's
01	Ø1 and Ø2.5	2.5, 5, 10, 30.
02	Ø5	62.5, 125, 250, 750.
03	Ø10	3000.

VICKERS HARDNESS TEST

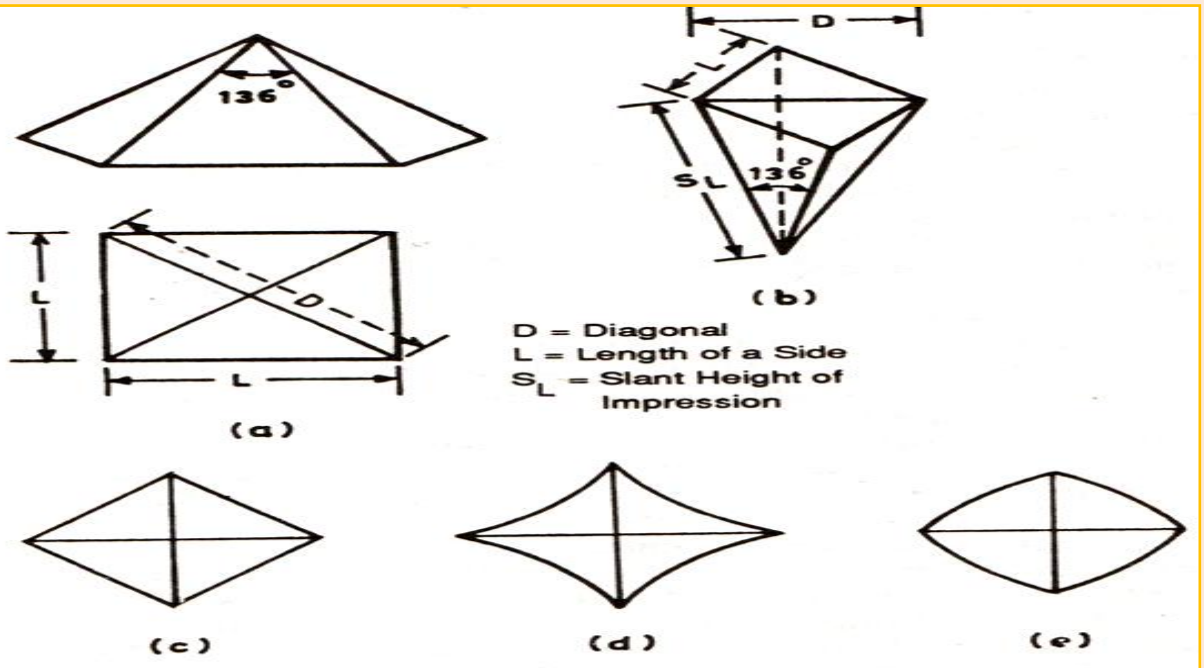


Fig. 18.4 Geometry of (a) indentor; (b) indentation in Vickers hardness tester; (c) perfect indentation; (d) pin cushion indentation (due to sinking in); and (e) barrelled indentation (due to ridging).

1. In this test, the hardness number is obtained from the relationship between the applied load & surface area of the indentation.
2. A square based pyramid with an included angle of 136˚ is impressed on a flat polished surface of hard material.
3. The applied load is 5kg, 10kg, 100kg or 120kg depends on the thickness and hardness of the specimen. These loads are applied for 10 to 15seconds.
4. The Vickers hardness number or diamond pyramid number is obtained as follows.

$$\mathbf{H_v = \frac{1.8544P}{d^2}}$$

Where,

V.P.N = Vickers penetration (pyramid) number.
D.P.N = Diamond pyramid hardness number.
P = Applied load in Kgs.
D = Diagonal on impression produced in mm.

ADVANTAGES:

1) Most accurate &produce small indentation.
2) It can be used for verify of material from very soft to extreme hard materials.
3) It is used for research worktable, which will give different hardness.

ROCKWELL HARDNESS TEST

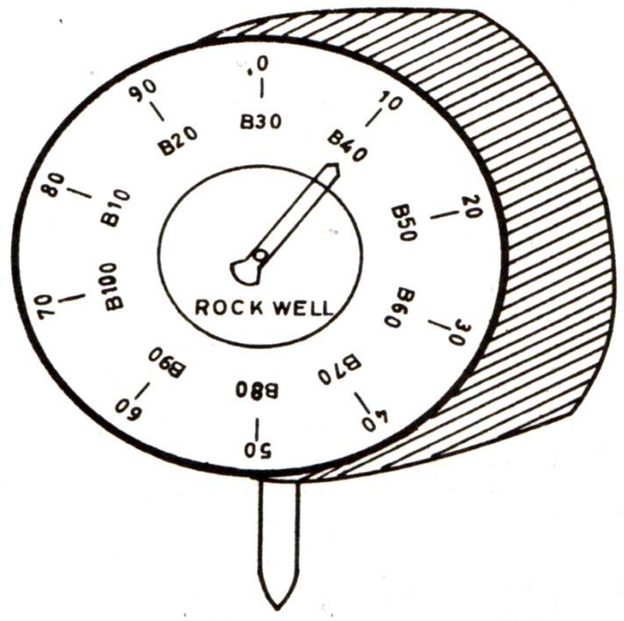


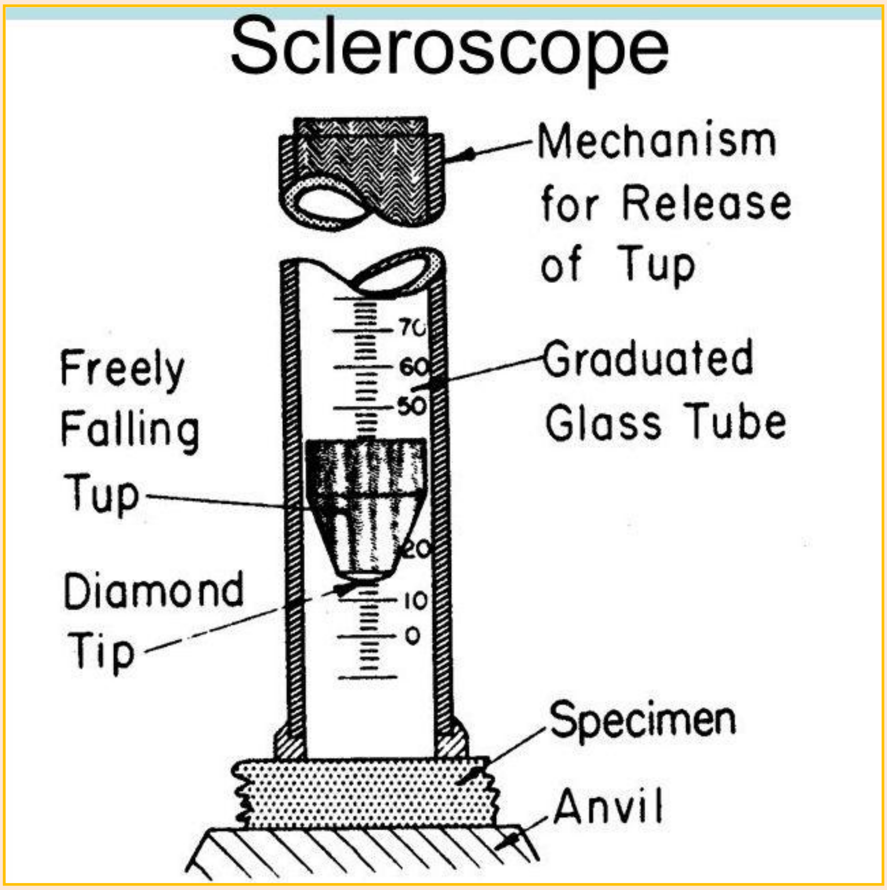
Fig. 18.5 Rockwell hardness tester dial.

1. The Rockwell hardness machine determines the hardness of the metal from the depth of penetration made by a steel bar or a diamond cone.
2. The metal to be tested is loaded on the machine & is raised up until the metal comes into contact with the indentor.
3. A small load called minor load of 10kg is applied by raising the metal to a definite position on the dial gauge. This position on the dial is called the zero position.
4. The major load of 50kg, 90kg, or 140kgis applied by means of levers & therefore, the indentor is forced down into the metal.
5. The major load is now removed. The indentor is now under the effect of the minor load only.
6. This test produces relatively smaller indentation & gives the hardness number directly on the machine.

7. No table need to be referred. Therefore, it is simpler & quicker than the Brinell test & hence widely used in industries.
8. Depending on the job to be tested, different combinations of loads & indentors are used.
9. The conical shaped diamond called a brace with 120˚ apex angle & 0.2mm radius is called as indentor for softer materials a hardened steel ball of dia 1.5mm is used & number of different scales are used namely A, B, C, N, T.
10. A 120° diamond cone, also known as Brale indenter

Scale	Indenter	Major load (kg)	Dial Numerals	Applications
A	Brale	60	Black	For measuring very hard materials(ex: cemented carbides, ceramics cermets and case hardened surfaces)
B	1/16'' diameter ball	100	Red	Copper and aluminium alloys and unhardened steels
C	Brale	150	Black	Hardened steels, cast irons, titanium alloys and case-hardened surfaces
D	Brale	100	Black	Razor blades and certain case hardened surfaces

REBOUND METHOD



1. This test is done using a machine called the Shore Sceleroscope.
2. In this test, the hardness is measured by measuring the rebound of an indentor that is dropped on to the metal from a certain height.
3. The machine consists of a graduated about 250mm long & a small cylindrical diamond tip weight of 2.5gms drops through the tube on the metal surface.
4. Depending on the hardness of the metal, the rebound of the indentor varies.
5. The indentor stops when it reaches a maximum height of rebound.
6. The harder the material more will be the rebound. The tube is divided into 40equal divisions.
7. The Shore Sceleroscope is a portable machine employed for testing the hardness of huge work pieces like machine bed which cannot be loaded on the hardness machine.
8. It is used in applications where any indentation is not tolerated.
9. But this method has inherent limitations in the accuracy associated with the measurement of the height of rebound.

UNIT 8 – CLASSIFICATION OF STEELS

CASE HARDENING STEELS

1. A tough core and a hard case are the desired attributes of case hardened steel components.
2. This combination of properties provides wear resistance and fatigue strength at the surface, and impact strength in the core.
3. It is achieved by carburizing the components surface, then quenching and tempering the part.
   Ex: Gears, Arbours, Camshaft, Driving pinions universal joints etc.

HOT ROLLED STEELS

1. Hot rolling is a mill process which involves rolling the steel at a high temperature 920°C, which is above the steels recrystallization temperature.
2. When steel is above the recrystallization temperature, it can be shaped and formed easily. And the steel can be made in much larger sizes.
3. Hot rolled steel is typically cheaper than cold rolled steel due to the fact that it is often manufactured without any delays in the process.
4. When the steel cools off it will shrink slightly thus giving less control on the size.

Uses:
hot rolled products like hot rolled steel bars are used in the welding and construction trades to make rail road tracks and I-beams, for ex: hot rolled steel is used in situations where precise shapes and tolerances are not required.

COLD ROLLED STEELS

The steel is processed further in cold reduction mills, where the material is cooled followed by annealing or tempers rolling. This process will produce steel with closer dimensional tolerances and a wider range of surface finishes. The term cold rolled is mistakenly used on all products, when actually the product name refers to the rolling of flat rolled sheet and coil products. This usually consists of cold drawing, turning, grinding, and polishing. This process results in higher yield points and tensile strength.

Four main advantages:

- Cold drawing increases the yield and tensile strength often eliminating further costly thermal treatments.
- Turning gets rid for surface imperfection.
- Grinding narrows the original size tolerance range.
- Polishing improves surface finish.

Uses:

Any project where tolerances surface condition, concentricity and straightness are major factors, and reamers, taps, press blanking and stamping.

SPRING STEELS

1. Spring steel is a name given to a wide range of steels used widely in the manufacture of springs.
2. These steels are generally low-alloy, medium –carbon steel or high carbon steel with a very high yield strength.
3. This allows objects made of spring steel to return to their original shape despite significant deflection or twisting.
4. High quality springs are made from chromium and vanadium steels
5. Applications: automobile, aircraft, engine valve, piano wire, antennas, leaf springs etc

FREE CUTTING STEELS

1. Free cutting steels or free machining steels are those with enhanced machinability.
2. Main characteristics are: speed of machining, surface finish of the machined components, tool life of the cutting tools employed for machining operation.
3. These steels form small chips when machined.

4. This increases the machinability of the material by breaking the chips into small pieces thus avoiding entanglement in the machinery.
5. Free cutting steels are carbon steels that have sulphur, lead or phosphorus.
6. Sulphur forms the compound manganese sulphide which is soft and as a chip-breaking discontinuity.

STRUCTURAL STEELS

These steels are used as a construction material for making structural steel shapes, a structural steel shape is a profile formed with a specific cross section.

TOOL STEEL

Tool and die steels may be defined as special steels which have been developed to form, cut or otherwise change the shape of a material into a finished or semi finished product.

CHARACTERISTICS OF TOOL AND DIE STEELS

TOOL STEEL GRADES

WATER HARDENING STEELS (W-Grades):

This is basically a high carbon steel. While it generally has a lower cost it cannot be used where high temperatures are involved. This steel can achieve a high hardness, but it is rather brittle when compared to other tool steels. All W-grade tool steels must be water quenched, which can lead to increase warping and cracking.

Applications:

Cold hardening, cutting tools, knives, embossing, reamers and cutlery,

AIR HARDENING STEELS (A-Grades):

This is a very versatile, all purpose tool steel that is characterized by low distortion factor during heat treatment, due to the increased chromium content. This tool steel has good machinability and a balance of wear resistance and toughness.

Applications:

Die bending, blanking, coining, embossing, cold forming, lamination, cold swaging, cold trimming, gages, chipper knives, cold shear knives, wood working knives, lathe centre knives.

D-Grades:

This is a high carbon, high chromium tool steel. It was formulated to combine both the abrasion resistance and air-hardening characteristics.

Applications:

Burnishing tool, file cutting, paper cutters, die bending, blanking, coining, wood work knives, knurling tools wire drawing, cold swaging etc.

OIL HARDENING STEELS (O-Grades):

This is general purpose oil hardening tool steel. It has good abrasion resistance and toughness for a wide range of applications.

Applications:

Bushing, chasers, collets, drill bushing etc.

SHOCK RESISTANCE STEELS (S-Grades):

This type of tool steel has been designed to resist shock at low or high temperatures (ex: Jack hammer bits). Its low carbon content is required to achieve the necessary toughness. This group of metals has high impact toughness, but a low abrasion resistance.

Applications:

Battering tools, boiler-shop tools, chisel blacksmiths, chisel cold hot working, chuck jaws, clutch parts, cold and hot shear, chipper knives

BLACK BARS:

The black bars available with us are manufactured using hot forming process. These mild steel black bars process scale coating on the surface and is majorly used while welding applications.

The steel is not considered ideal for making machining parts. These bars are available in different finishes and grades as per the requirements of the clients.

BLACK ROUND BARS:

These are available in sizes ranging from 10mm to 600mm with make options including rolling. These steel round bars are used in fabrication of engineering components. The low carbon steel is used that do not contain any alloying elements and carbon content will also not exceed by 0.25%.

Features:

- Used in mechanical engineering applications.
- Allows tight section tolerance.
- Increase straightness with comparatively clean and cold drawn surface finish.

Applications:

- Engineering components
- Forging industries
- Foundation bolts
- Shafting applications

BLACK SQUARE BARS:

These are available in sizes of 10mm to 200mm in rolling, these steel square bars find use in the fabrication of machined components

Features:

- Suitable for applications in forging industries, grill fencing and engineering components.
- Available in both metric and imperial options.
- Available in cut to size finish.
- Bars produced using cold finishing process.

Applications:

- Daily equipments.
- Surgical & medical parts.
- Hinges and handles.

BLACK FLAT BARS:

These are available in sizes from 20*3mm to 300*20mm in rolling.
These steel flat bars are used in general engineering fabrication that require high strength steel, component manufacturing and in grating industries.

Features:

- Allows tempering at high temperature.

- Available in quenched finish using oil/water.
- Suitable for engineering applications that require steel of superior strength.

Applications:

- Electrical & machinery industries.
- General engineering and fabrication jobs.
- Grating industries.
- Component manufacturing.