KARPAGAM ACADEMY OF HIGHER EDUCATION

COIMBATORE – 21

FACULTY OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

17BEME404A INDUSTRIAL METALLURGY 3 0 0 3 100

OBJECTIVES

To impart knowledge on the structure, properties, treatment, testing and applications of metals and non-metallic materials so as to identify and select suitable materials for various engineering applications.

UNIT I CONSTITUTION OF ALLOYS AND PHASE DIAGRAMS 9

Constitution of alloys – Solid solutions, substitutional and interstitial – phase diagrams, Isomorphous, eutectic, peritectic, eutectoid and peritectoid reactions, Iron – Iron carbide equilibrium diagram -Classification of steel and cast Iron, microstructure, properties and applications.

UNIT II HEAT TREATMENT 9

Definition – Full annealing, stress relief, recrystallisation and spheroidizing –normalising, hardening and tempering of steel. Isothermal transformation diagrams – cooling curves superimposed on TTT diagram, CCT Hardenability, Jominy end quench test – Austempering, martempering – case hardening - carburising, nitriding, cyaniding, carbonitriding – Flame and Induction hardening, Microstructure study and specimen preparation.

UNIT III FERROUS AND NON FERROUS METALS 9

Effect of alloying elements on steel (Mn, Si, Cr, Mo, V, Ti & W) - stainless and tool steels – HSLA – maraging steels – Gray, White malleable, Spheroidal Graphite irons - Copper and Copper alloys – Brass, Bronze and Cupronickel – Aluminum and Al-Cu – precipitation, strengthening treatment – Bearing alloys.

UNIT IV NON-METALLIC MATERIALS 9

Polymers – types of polymer, commodity and engineering polymers – Properties and Applications of thermoplastics (PP, PVC, ABS, and PMMA) and thermosetting plastics (PF, UF, MF) –Engineering Ceramics.

UNIT V TESTING OF MECHANICAL PROPERTIES AND INSPECTION 9

Mechanism of plastic deformation, slip and twinning – Types of fracture – Testing of materials under tension, compression and shear loads – Hardness tests (Brinell, Vickers and Rockwell), Impact test - Izod and Charpy, Fatigue and creep test, S-N curve.

Non Destructive Testing: Non Destructive Testing basic principles and testing method of Radiographic testing, Ultrasonic testing, Magnetic particle test and Liquid penetrant test, Eddy current testing.

TOTAL 45

TEXT BOOKS

S. No.	Author(s) Name	Title of the book	Publisher	Year of Publication

1	Kenneth G.Budinski and Michael K.Budinski	Engineering Materials	Prentice-Hall of India Private Limited, New Delhi	2010

REFERENCES

S. No.	Author(s) Name	Title of the book	Publisher	Year of Publication
1	William D. Callister & David G. Rethwisch	Material Science and Engineering	John Wiley and Sons, Delhi	2013
2	Raghavan.V	Materials Science and Engineering	Prentice Hall of India Pvt., Ltd, New Delhi	2015
3.	Shackelford. J.F	Introduction to Materials Science for Engineers	Pearson Edition	2014

WEB REFERENCES:

1. www.materials.unsw.edu.au
2. ocw.MIT.edu
3. www.istl.org
4. metalurgy-screw-tutorial.tobyavujo.com

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COIMBATORE – 21

FACULTY OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE PLAN

Subject Name : **Industrial Metallurgy**
Subject Code : **17BEME404A** **(Credits -3)**
Name of the Faculty : **Dr.S.Manivannan**
Designation : **Associate Professor**
Year/Semester : **II/IV**
Branch : **Mechanical Engineering**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – I : CONSTITUTION OF ALLOYS AND PHASE DIAGRAMS			
1.	1	Constitution of alloys – Solid solutions, substitutional and interstitial	R1 (Pg no:286-289)
2.	1	Phase diagrams, Isomorphous, eutectic	T1 (Pg no: 293-294) R1 (Pg no: 318-322)
3.	1	Peritectic, eutectoid and peritectoid reactions	R1 (Pg no:357) R4 (Pg no:54-58)
4.	1	Iron –Iron carbide equilibrium diagram	R4 (Pg no:68-72)
5.	1	Classification of steel and cast Iron	R1 (Pg no:378-406) &W1
6.	1	Microstructure, properties and applications of steel	W1
7.	1	Microstructure, properties and applications of cast Iron	W1
Total No. of Hours Planned for Unit - I			**7Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – II : HEAT TREATMENT			
8.	1	Heat treatment definition	R2 (Pg no:1)& W2
9.	1	Full annealing and Stress relief annealing	R2(Pg no:88-91)
10.	1	Recrystallisation annealing and Spheroidzing annealing	R2(Pg no: 91-92)
11.	1	Normalizing heat treatment	R2(Pg no: 94-98)
12.	1	Hardening heat treatment	R2(Pg no: 94-98)
13.	1	Tempering of steel and Difference between normalizing and hardening	R2(Pg no: 100-103)

14.	1	Isothermal transformation diagrams – cooling curves superimposed on TTT diagram and CCT	R2(Pg no: 61-67)
15.	1	Hardenability and Jominy end quench test	R2(Pg no: 108-113)
16.	1	Austempering and martempering	R2(Pg no: 104-105)
17.	1	Case hardening, and carburising	R2(Pg no: 130-133)
18.	1	Nitriding and cyaniding	R2(Pg no: 137-140)
19.	1	Carbonitriding – Flame and Induction hardening	R2(Pg no: 145-146)
Total No. of Hours Planned for Unit - II			**12 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – III : FERROUS AND NON FERROUS METALS			
20.	1	Effect of alloying additions on steel (Mn, Si, Cr, Mo, V, Ti and W)	R4(Pg no:155-156)
21.	1	Stainless and tool steels	R4 (Pg no:242-247) R2(Pg no: 156-160
22.	1	HSLA and maraging steel	R2(Pgno:247-248)
23.	1	Gray, White malleable, spheroidal cast iron	R4(Pg no:180-199)
24.	1	Copper and Copper alloys – Brass, Bronze and Cupronickel	R2 (306-307)
25.	1	Aluminum and Al–Cu	R2(Pg no:277)& W3
26.	1	Precipitation strengthening treatment – Bearing alloys.	R2 (Pg no:246-247)
Total No. of Hours Planned for Unit - III			**7 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – IV : NON–METALLIC MATERIALS			
27.	1	Polymers – types of polymer, commodity and engineering polymers	R1(Pg no:449) R5 (pg no:163-165)
28.	1	Properties and applications of thermoplastics PP & PVC	R1 (Pg no:457-460)
29.	1	Properties and applications of thermoplastics ABS & PMMA	R1(Pg no:457-460)
30.	1	Properties and applications of thermosetting plastics PF & UF	R1 (Pg no:478)&R4
31.	1	Properties and applications of thermosetting plastic MF	R1 (Pg no:478)&R4
32.	1	Engineering Ceramics	R1 (Pg no:490-493)
33.	1	Types of ceramics and its applications	R1(Pg no:524-539)
Total No. of Hours Planned for Unit - IV			**7 Hours**

COURSE PLAN

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – V : TESTING OF MECHANICAL PROPERTIES AND INSPECTION			
34.	1	Mechanism of plastic deformation, slip and twinning	R1 (Pg no:237-249)
35.	1	Types of fracture and Testing of materials under tension	R1 (Pg no:186-203), R1 (Pg no:158-166)
36.	1	Testing of materials under compression loads	R1 (Pg no:170-173)
37.	1	Testing of materials under shear loads	R1 (Pg no:172-173)
38.	1	Hardness tests -Brinell Hardness tests, Vickers Hardness test and Rockwell Hardness test	R1 (Pg no:174-175)
39.	1	Impact test – Izod and Charpy theory and laboratory.	R1 (Pg no:175-179)
40.	1	Fatigue and creep properties	R1 (Pg no:203-215)
41.	1	S–N curves fatigue and creep testing and toughness tests	R1 (Pg no:209)
42.	1	Non Destructive Testing basic principles	R6(Pg no:1-6)
43.	1	Testing method for Radiographic testing and Ultrasonic testing	R6(Pg no:90), R6(Pg no:57)
44.	1	Magnetic particle inspection and Liquid penetrant test	R6(Pg no:18), R6(Pg no:7)
45.	1	Eddy current test	R6(Pg no:32)
Total No. of Hours Planned for Unit - V			**12 Hours**

TOTAL PERIODS : 45 Hours

TEXT BOOK:

S.NO	AUTHOR(S) NAME	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1.	Kenneth G.Budinski and Michael K.Budinski	Engineering Materials	Prentice–Hall of India Private Limited , New Delhi.	2010

REFERENCE BOOKS:

S.NO	AUTHOR(S) NAME	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1.	Donald R Askeland, Pradeep P. Fulay,D.K.Bhattachaya	Material Science and Engineering	Cenage Learning India Pvt., Ltd, Delhi.	2011

2.	T.V.Rajan,C.P.Sharma and Ashok sharma	Heat treatment principles and techniques	PHI Learning Pvt.,Ltd, Delhi.	2013
3.	Raghavan.V	Materials Science and Engineering	Prentice Hall of India Pvt., Ltd, New Delhi.	2006
4.	Dr.Srinivasan	Material science and metallurgy	Tata Mc graw hill publications	2010
5.	William D. Callister and David G. Rethwisch	Material Science and Engineering	John Wiley and Sons, Delhi	2010
6.	Barry Hull and Vernon Hull	Non destructive testing	English language book society,Macmillan	2002

WEBSITE REFERENCE:

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3. www.msm.cam.ac.uk
4. www.pfri.uniri.hr
5. www.esmat.esa.int/sme2

UNIT	Total No. of Periods Planned	Lecture Periods	Tutorial Periods
I	**7**	**7**	**NA**
II	**12**	**12**	**NA**
III	**7**	**7**	**NA**
IV	**7**	**7**	**NA**
V	**12**	**12**	**NA**
TOTAL	**45**	**45**	**NA**

1. Internal Marks : 40 Marks

S.NO	Test	Marks
1.	CIA-I	15
2.	CIA-II	15
	Total	**30**

- **Internal Assessment Tests : 30Marks**
- **Attendance : 5 Marks**
- **Seminar : 5 Marks**

2. End Semester Examination	**: 60 Marks**
TOTAL	**: 100 Marks**

FACULTY **HOD** **DEAN**

UNIT-I

SOLID SOLUTION:

A solid solution is an alloy in which the solute atoms are distributed in the solvent matrix and has the same structure of the solvent. The element which is present in a larger amount in the alloy is called solvent and the other elements are called solute.

A solvent is a substance which dissolves a solute. When a solvent dissolves into a solute, it creates a solution.

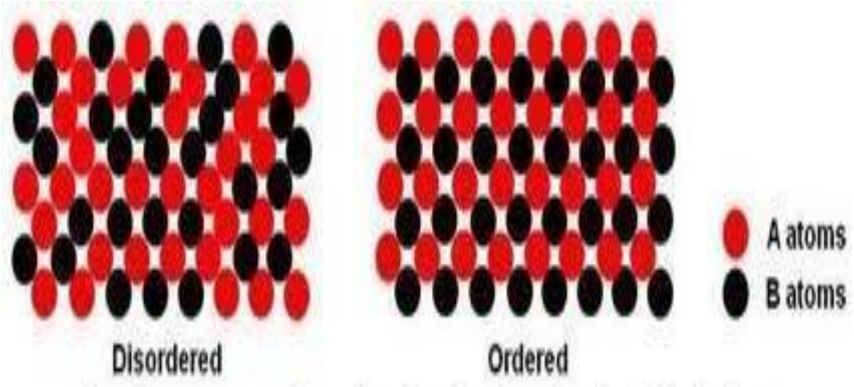
Solid solutions are of two types:

1. **Substitutional solid solution**
2. **Interstitial solid solution**

Substitutional solid solution:

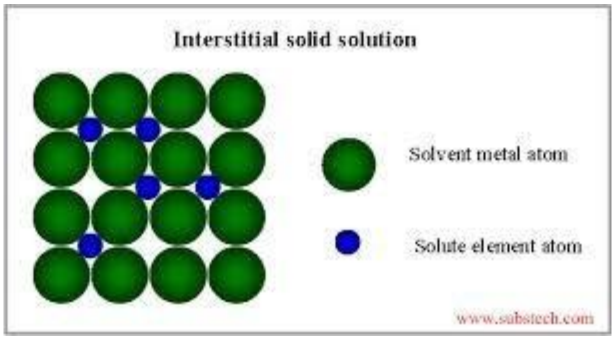
In a substitutional solid solution, the atoms of the solvent metal are replaced in the crystal lattice by atoms of the solute. Substitutional solid solution formation is favoured when the atomic sizes of two metals are almost equal.This substitution is either **ordered or disordered.**

In ordered substitutional solid solution,the substitution of either atoms in solvent is by a definite order, while this is not so in disordered solid solution.



Atomic arrangement in a disordered and ordered solid solutions

Interstitial solid solution:



Interstitial solid solutions are formed when the atoms of the solute element are very small compared with those of the solvent, thus enabling them to fit into the interstices or spaces in the crystal lattice of the solvent.

Iron iron carbon equillibrium diagram:

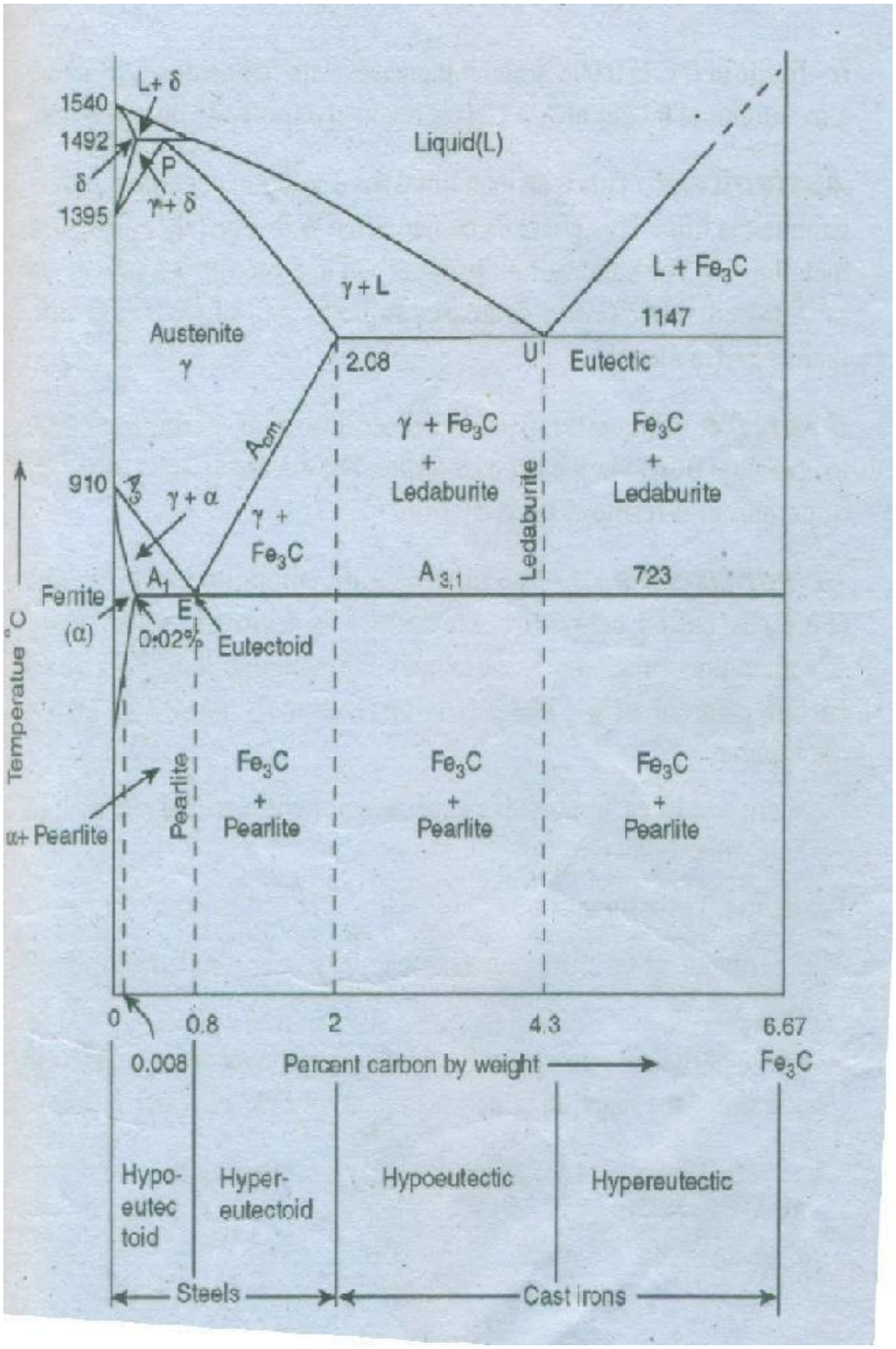


Figure: Iron iron carbon equllibrium diagram

Iron iron carbon equllibrium diagram provides the basis for understanding thr properties and heat treatment of steel and effect of alloying elements in alloy steel.

The $FeFe_3C$ diagram plotted for concentration weight % up to 6.67% carbon. This is not a true equilibrium diagram because the compound iron carbide is not a true equilibrium phase.

Under proper conditions iron carbide decomposes to form more stable carbon graphite. This decomposition is almost never observed in ordinary steels so iron carbide is considered as stable and therefore treated as an equilibrium phase.

The Iron iron carbon equilibrium diagram is divided into two parts 2% carbon known as steel and those containing more than 2% carbon known as cast iron.

The Iron iron carbon equilibrium diagram contains the following solid phases.

α -Ferrite:

- **This is an interstitial solid solution of carbon in BCC alpha iron.**
- **The solubility of carbon in α –Ferrite at 0^0C is 0.008% and it increases with temperature up to 0.02% at 723^0C.**
- **It is a soft and ductile phase.**

Austenite γ:

- **This is an interstitial solid solution of carbon in FCC gamma iron**
- **The solubility of carbon in austenite is maximum of 2% at 1147^0C and decreases to 0.8% at 723^0C.**
- **It is a soft, ductile and malleable phase.**

δ-Ferrite:

- **This is an interstitial solid solution of carbon in BCC alpha iron.**
- **The maximum solubility of carbon in δ-ferrite is 0.1% at 1492^0C**

Cementite (Fe_3C):

- **This is an intermetallic compound of iron carbide.**
- **Fe3C is also called as cementite**
- **This compound has fixed carbon content of6.67%**
- **It is a hard and brittle compound.**

There are three transformation regions involved in $FeFe_3C$ diagram in the heat treatment of steel.

1. Peritectic transformation:

Liquid+ δ-Ferrite-------- > Austenite γ

At the peritectic point P, all liquid combines with δ-Ferrite to form Austenite γ at 1492^0C.

2. Eutectoid transformation:

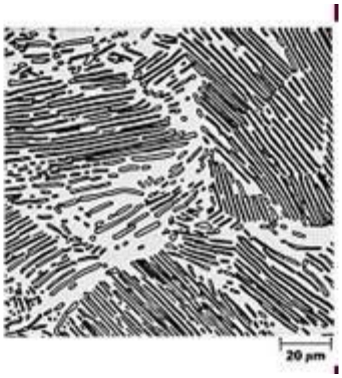
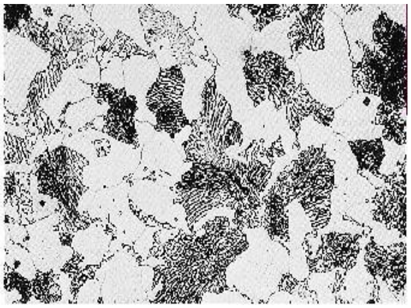
Austenite γ --------> α –Ferrite + Cementite (Fe_3C)

At the Eutectoid point E solid austenite produces very fine eutectoid mixture of α Ferrite and cementite. This mixture contains alternate layers of ferrite and cementite and is called „Pearlite‟.

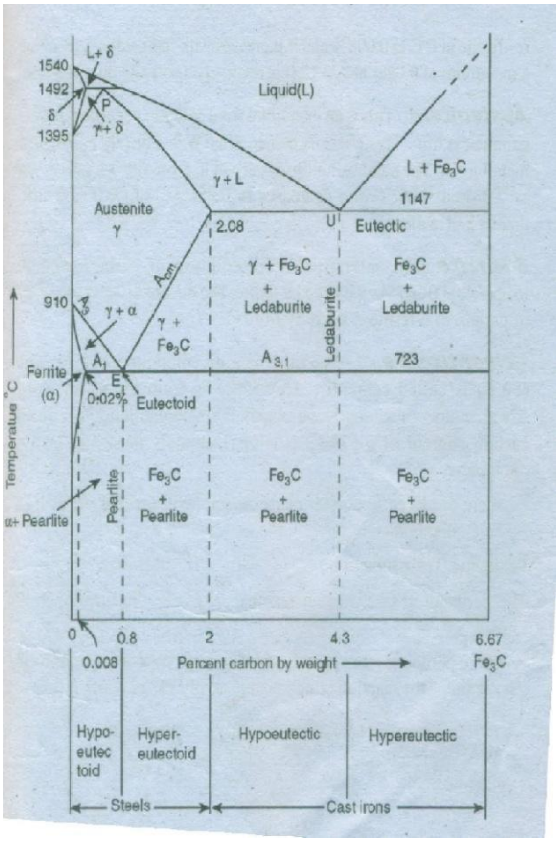
3. Eutetic transformation:

Liquid ------- > Austenite γ + Cementite (Fe_3C)

At the eutectic reaction point U, liquid transforms and gives a very fine eutectic mixture of austenite and cementite.This eutectic mixture is called as ledaburite.

Eutectoid steel	**Hypoeutectoid steel**	**Hypereutectoid steel**
		

Changes that take place during the slow cooling of 0.5% carbon steel from liquid state.



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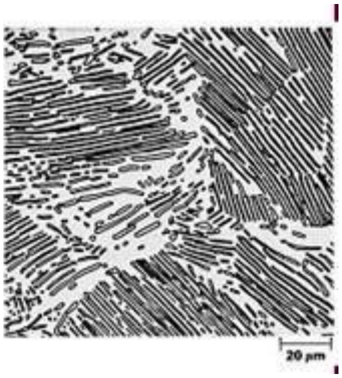
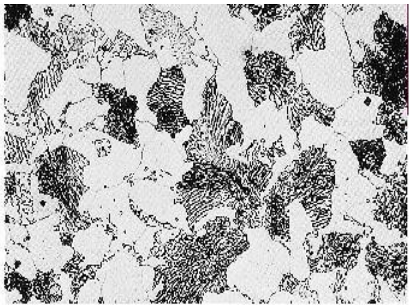
At the Eutectoid point E solid austenite produces very fine eutectoid mixture of α Ferrite and cementite. This mixture contains alternate layers of ferrite and cementite and is called „Pearlite‟. This reaction occurs at 723^0C.

3. Eutetic transformation:

Liquid ------- > Austenite γ + Cementite (Fe_3C)

At the eutectic reaction point U, liquid transforms and gives a very fine eutectic mixture of austenite and cementite.This eutectic mixture is called as ledaburite.

Eutectoid steel	Hypoeutectoid steel	Hypereutectoid steel
		

Microconstituents of iron-carbon alloys

Main micro-structures of iron carbon alloy in equilibrium are

Austenite :

– Austenite is a high temperature phase and has a Face Centred Cubic (FCC) structure (which is a close packed structure). Iron is having good strength and toughness but it is unstable below 723 deg C

Ferrite:

– It is relatively soft low temperature phase and is a stable equilibrium phase. Ferrite is a common constituent in steels and has a Body Centred Cubic (BCC) structure (which is less densely packed than FCC). ?-iron is soft , ductile and has low strength and good toughness.

Cementite :

– It is Fe3C or iron carbide. It is intermediate compound of Fe and C. It has a complex orthorhombic structure and is a metastable phase. It is hard, brittle and has low tensile strength, good compression strength and low toughness.

Pearlite:

Pearlite is the ferrite-cementite phase mixture. It has a characteristic appearance and can be treated as a micro structural entity or micro constituent. It is an aggregate of alternating ferrite and cementite lamellae that degenerates (“spheroidizes” or “coarsens”) into cementite particles dispersed with a ferrite matrix after extended holding below 723 deg C. It is a eutectoid and has BCC structure. It is a partially soluble solution of Fe and C. It has high strength and low toughness.
In case of non-equilibrium solidification of Fe-C system martensite and sorbite may form.

MCQ

Questions	opt1	opt2	opt3	opt4	answer
The materials in which the atoms are arranged in some regular repetition pattern are called	Crystalline materials	Non-crystalline materials	Amorphous materials	None of the above	Crystalline materials
An example for amorphous material is	All metals	Ceramics	Glass	None of the above	Glass
A Unit Cell is characterized by	Coordination number	Atomic radius	Atomic packing factor	All of these	All of these
Coordination number of Simple Cubic Lattice is	4	6	8	12	4
The capacity of a material to undergo deformation under tension without rupture is known as	Mechanical strength	Stiffness	Toughness	Ductility	Ductility
Study of atomic structure of metals is useful	To understand the type of atomic bonding	To understand the structure – property relationships.	To understand the various factors that determines the crystal structure.	All of these	All of these
Large angle grain boundary defects are associated with	Point defects	Line defects	Surface defects	Volume defects	Surface defects
Point defects are related to	Tilt boundary/ twist boundary	Voids/ stacking faults	Self interstitials & vacancy	d)Edge dislocations	Self interstitials & vacancy
Line defects are related to	Tilt boundary/ twist boundary	Voids/ stacking faults	Self interstitials & vacancy	d)Edge dislocations	Edge dislocations
Surface defects are related to	Tilt boundary/	Voids/ stacking faults	Self interstitials & vacancy	d)Edge dislocations	Tilt boundary/ twist

	twist boundary				boundary
Volume defects are related to	Tilt boundary/ twist boundary	Voids/ stacking faults	Self interstitials & vacancy	Edge dislocations	Voids/ stacking faults
The crystal structure of Silver is	FCC	BCC	HCP	None of the above	FCC
A chemically and structurally homogeneous portion of a microstructure is called a	Phase	Compound	Solid solution	None of the above	Phase
________means that the properties are same in all directions in a metallic sample.	Polymorphism	Allotropy	Isotropy	None of the above	Isotropy
Alloying is carried out to improve the strength and hardness of the material. If an alloy has a single phase it could be a	Pure metal	Solid solutions	Intermediate phase	Solid solution or an intermediate phase	Solid solution or an intermediate phase
Name the rule which determines solid solubility	Gibbs rule	Hall-petch effect	Hume-Rothery rule	Both a and b	Hume-Rothery rule
If the atomic sizes of solute and solvent differ by less than -------------,conditions are favourable for the formation of a solid solution.	20%	15%	30%	10%	15%
When one element is electronegative and the other electropositive, ----------------- is formed	Substitutional Solid solution	Intermediate phase	There is no such relation	Interstitial solid solution	Intermediate phase
Gibbs phase rule is given by the equation	P+F=C+1	P+F=C	F=P-C+2	P+F=C+3	P+F=C+1
The important information that can be gathered from phase diagrams is	Number of phases present	Composition of phases	Amount of each phase	All of these	All of these

2 marks

1. Write the constitution of austenite.

   Austenite is a primary solid solution based on γ iron having FCC structure. The maximum solubility of carbon in FCC iron is about 2% at 1140^{0}C.
2. Classify plain carbon steel.

   Low carbon steel – less than 0.25% carbon, Medium carbon steel – 0.25% to 0.60% carbon, High carbon steel – more than 0.60% carbon.
3. Define Alloy.

   It is a mixture of two or more metals or a metal and a non metal
4. What are alloying elements?

   The element which is present in the largest proportion is called the base metal and all other elements presents are called alloying base elements.
5. How will you explain peretectic reaction?

   In peretectic reaction, up on cooling, a solid and a liquid phase transform isothermally and reversibly to a solid phase having a different composition.
   Liquid + Solid1== solid2
6. What is steel?

   Steel is a composition unto 0.008% carbon is regarded as commercially pure iron those from 0.008-2% Carbon represent the steel.
7. State the condition for Gibb's phase rule.

   Pressure variable is kept constant at one atmosphere
   Gibb phase rule F=c-p+2; F=c-p+1(condensed Gibb phase rule).
8. Explain base metal.

   The element which present in the largest proportion is called the base metal
9. Differential between substitution and interstitial solid solutions.

   When the solute (Impurities) substitutes for parent solvent atoms in a crystal lattice, they are called substitution atoms, and the manure of the two elements is called a substitution solid solution.
10. What are alloying elements?

    In an alloy, all elements other than the base metal are called the alloying elements.
11. Substitutional and interstitial solid solutions-Differentiate.
    - In a substitutional solid solution, the solute atoms substitute for parent solvent atoms in a crystal lattice.
    - In interstitial solid solution, the solute atoms fit into the space between the solvent or parent atoms.
12. What are inter metallic compounds?

    The compounds formed by two or more metals in apparently stoichiometric proportion is called inter metallic compounds
13. Explain the effects of crystal structure and atomic radii on formation of solid solution between two metallic elements.

    Hume Rothery's Rules
    - Crystal structure: The two metallic elements that form solid solution must have the same crystal structure. Otherwise, there is some point at which a transition occurs from one phase to a second phase with a different structure.
    - Atomic radii: The solute and solvent elements atoms must be of similar size, with less than a 15% difference in atomic radius.

14. Define the term “ferrite” and “austenite” in iron – carbon alloy system.

    Ferrite is primary solid solution based on α iron having BCC structure. Austenite is a primary solid solution based on γ iron having FCC structure. Both are interstitial solid solutions of carbon in iron.

15. Explain “allotropy of iron”

    Allotropy refers to the possibility of existence of two or more different crystal structure for a substance depending upon temperature.

16. Why carbon solubility is more in an austenite?

    Austenite is a primary solid solution based on γ iron having FCC structure. Carbon solubility is more in austenite is an interstitial solid structure of carbon in iron.

17. Distinguish between hypoeutectic and hypereutectic cast irons.

    Cast irons that contain less than 4.3 % carbon are termed as hypoeutectic whereas cast iron that contains more than 4.3 % carbon is termed as hypereutectic cast irons.

18. State Gibb’s phase rule.

    Gibb’s phase rule is given by

    $F = C - P + 2$, Where, F – Degrees of freedom of system or the no. of variables that may be changed independently without altering the equilibrium, C – No. of components forming the system, P – Number of phases present in the system

19. What are intermediate phases?

    If an alloying element is added in excess of the limit of solid solubility, a second phase appears along with the primary solution. If the second phase is differs in both crystal structure and properties from primary solid solution, than it is known as an intermediate phases.

20. How do cast irons differ from steels in terms of carbon content?

    Composition from 0.008 to 2% carbon represent steel and those above 2% carbon represent cast iron

21. Write the Hume-Rothery rules for substitutional solid solutions (or) State the conditions under which two metallic will exhibit unlimited solid solubility.

    Hume – Rothery rules govern the formation of sustitutional solid solutions.

    1. Crystal Structure factor

       The crystal lattice structure of the two elements (metal) should be same for complete solubility; otherwise the two solutions would not merge into each other. Also, for complete solid solubility the size factor must usually be less than 8 %.

    2. Relative size Factor

       If two metals are to exhibit extensive solid solubility in each other it is essential that their atomic diameters shall be fairly similar.

    3. Chemical affinity Factor

       The greater the chemical affinity of two metals, the more restricted is their solid solubility. When their chemical affinity is great, two metals tend to form an intermediate phase rather than a solid solution.

    4. Relative Valence factor

       The metal of high valence can dissolve only a small amount of a lower valence metal, while the lower valence metal may have good solubility for the higher valence metal

22. What is the significance of phase diagram? (or) What is the information which can be obtained from phase diagram?

    - To show what phases are present at different at different compositions and temperatures under equilibrium conditions.
    - To indicate the equilibrium solid solubility of one element in another.

- To indicate the temperature at which an alloy cooled under equilibrium conditions starts to solidify and the temperature range over which solidification occurs.
- To indicate the temperature at which different phases start to melt.

23. Explain phase or equilibrium diagram.

A phase diagram is a graphical method of showing the phases present in an alloy system at different temperatures and different compositions.

24. How cast iron differ from steel?

Cast Iron	**Steel**
Ferrous with more than 2% of carbon	Ferrous with less than 2% of carbon
Is a brittle and tough metal	Is a ductile metal

25. What is Allotropy?

The possibility of existence of two or more different crystal structures for a substance is known as allotropy. Steel is the best example for the allotropy.

26. State the three classes of plain carbon steel.

1. Hypo- Eutectiod steel:

   These have carbon contents varying from 0.008% to just below 0.83%.

2. Eutectiod Steels:

   These have carbon content idly 0.83%

3. Hyper- eutectoid steel:

   These have carbon content varying from 0.83% to 1.8%.

27. Explain interstitial Solid Solution.

Solute atoms of smaller atomic diameters like Hydrogen, Carbon, Nitrogen, and Boron can occupy the empty spaces (interstices) in the crystal lattices of many metals. This type of solutions in the solid state is called as interstitial solid solution

Eg: Carbon in iron forms steel

28. Define Isomorphous.

The possibility of existence of two or more different crystal structures for a substance is known as allotropy.

29. What is Invarient Reaction? Give an Example.

Reaction in the solid solution in which the equilibrium may exists only under entirely definite conditions; at a constant temperature and at a definite composition of all phases involved.

30. Define Eutectic Reaction. Give an example.

When two metals are completely soluble in the solid state, it is called as eutectic reaction.Iron-carbon, aluminum– manganese, lead- tin, copper- nickel form an eutectic solution.

31. Write the Classification of steel.

I. Plain Carbon

steels

Low carbon Steel (Mild steel) – Carbon upto 0.25%
C Medium carbon steel - 0.25 to 0.55% C
High Carbon Steel (Tool Steel) - 0.6 to 1.5 % C

II. Alloys steels

Low alloy Steels - Alloying Elements upto 5%
Medium alloy Steels - Alloying elements 5 – 10 %
High alloy Steels - more than 10% of alloys.

32. What is peritectic Reaction? Write an example for that reaction.

Liquid and solid combines and form a new solid. The melting point of two metals differs considerably. Silver and platinum form such a system.

Liquid + Solid → New Solid

33. Write the different Classes of cast iron

Type	% of C	% of Si	% of Mn	% of P	% of S
Grey cast iron	2.5 – 3.8	1.1 – .8	0.4 – 1	0.15	0.10
White cast iron	2.0 – 2.3	0.85-1.2	0.10 – 0.40	0.05 – 0.2	0.12 – 0.35
Nodular cast iron	3.2- 4.2	1.1 – 3.5	0.3 – 0.8	0.08	0.2
Meallable cast iron	2-3	0.6 – 1.3	0.2 – 0.6	0.15	0.10

34. What is Eutectoid Reactions? Write an example of the eutectoid reaction occurs in the Iron Carbon System

This reaction is due to the transformation in solid state. Austenite à Ferrite + Cementite

14 MARKS

1. What are cooling curves? How does the time-temperature cooling curve of an alloy of eutectic composition differ from that of a pure metal that of a non–eutectic composition alloy?
2. How will you plot binary phase diagram for two metals which are completely soluble in liquid and solid states?
3. Explain the following invariant reactions with reference to a phase diagram (a) eutectic reaction (b) eutectoid reaction (c) Peretectic reaction (d) Peretectoid reaction.
4. What is the micro constituent of iron carbon alloys? Explain the general characteristics of each?
5. Draw Iron-iron carbide equilibrium diagram and mark on it all salient temperatures and composition fields.
6. Name the phase reactions occurring in Fe-Fe_3C system. What are the temperatures and compositions at which they occur?
7. Explain the primary crystallization of eutectoid steels hypo-eutectoid steels and hypereutectoid steels.

8. Define the primary crystallization of eutectic cast irons hypoeutectic cast irons and hypoeutectic cast iron with the help of neat sketch.
9. Explain in brief the properties and applications of cast Iron types.
10. Draw Fe-C diagram and mark all the phases and explain the reactions?
11. Explain the types of cast iron? Draw the microstructure of any four types of cast iron?
12. Brief Isomorphous phase diagram for Cu-Ni system and Ideal phase diagram (soluble and insoluble)
13. Explain Hume Rothery rule?
14. Explain the different types of carbon steel?

UNIT-II

HEAT TREATMENT

Annealing

Annealing refers to a wide group of heat treatment processes and is performed primarily for homogenization, recrystallization or relief of residual stress in typical cold worked or welded components. Depending upon the temperature conditions under which it is performed, annealing eliminates chemical or physical non-homogeneity produced of phase transformations. Few important variants of annealing are full annealing, isothermal annealing, spheroidise annealing, recrystallization annealing, and stress relief annealing.

A) Full annealing:

Full annealing process consists of three steps. First step is heating the steel component to above A3 (upper critical temperature for ferrite) temperature for hypo eutectoid steels and above A1 (lower critical temperature) temperature for hypereutectoid steels by 30-500 ºC

The second step is holding the steel component at this temperature for a definite holding (soaking) period of at least 20 minutes per cm of the thick section to assure equalization of temperature throughout the cross-section of the component and complete austenization. Final step is to cool the hot steel component to room temperature slowly in the furnace, which is also called as furnace cooling. The full annealing is used to relieve the internal stresses induced due to cold working, welding, etc, to reduce hardness and increase ductility, to refine the grain structure, to make the material homogenous in respect of chemical composition, to increase uniformity of phase distribution, and to increase machinability.

B) Spheroidization annealing:

It is a heat treatment process used for high carbon steels (Carbon > 0.6%) to improve machinability.

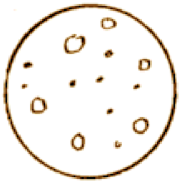
1. Heat the part to a temperature just below the Ferrite-Austenite line, line A1 or below the Austenite-Cementite line, essentially below the 723 ºC line. Hold the temperature for a prolonged time and follow by fairly slow cooling.

Or

2. Cycle multiple times between temperatures slightly above and slightly below the 723 ºC, say for example between 700 and 750 ºC and slow cool.

Or

3. For tool and alloy steels heat to 723 to 800 ºC and hold for several hours followed by slow cooling.



SPHEROIDITE

In this process no phase change takes place. The lamellar and free cementite coalesces into tiny spheroids due to surface tension effect. The final structure consists of spheroids of carbides in a matrix of ferrite.

The degree of spherodisation depends on temperature and holding time. More over fine pearlite coalesces more easily than the coarse pearlite.

C) Recrystallization annealing :

Recrystallization annealing process consists of heating a steel component below A1 temperature i.e. at temperature between 6250C and 6750C (recrystallization temperature range of steel), holding at this temperature and subsequent cooling. This type of annealing is applied either before cold working or as an intermediate operation to remove strain hardening between multi-step cold working operations. In certain case, recrystallization annealing may also be applied as final heat treatment. The cold worked ferrite recrystallizes and cementite tries to spheroidise during this annealing process. Recrystallization annealing relieves the internal stresses in the cold worked steels and weldments, and improves the ductility and softness of the steel. Refinement in grain size is also possible by the control of degree of cold work prior to annealing or by control of annealing temperature and time.

D) Stress relief annealing:

Stress relief annealing process consists of three steps. The first step is heating the cold worked steel to a temperature between 5000C and 5500C i.e. below its recrystallization temperature. The second step involves holding the steel component at this temperature for 1-2 hours. The final step is to cool the steel component to room temperature in air.

The stress relief annealing partly relieves the internal stress in cold worked steels without loss of strength and hardness i.e. without change in the microstructure. It reduces the risk of distortion while machining, and increases corrosion resistance. Since only low carbon steels can be cold worked, the process is applicable to hypo eutectoid steels containing less than 0.4% carbon. This annealing process is also used on components to relieve internal stresses developed from rapid cooling and phase changes.

Normalizing:

Normalizing process consists of three steps. The first step involves heating the steel component above the A3 temperature for hypoeutectoid steels and above Acm (upper critical temperature for cementite) temperature for hypereutectoid steels by 300 C to 500 C (Figure 4.7.5). The second step involves holding the steel component long enough at this temperature for homogeneous austenization. The final step involves cooling the hot steel component to room temperature in still air. Due to air cooling, normalized components show slightly different structure and properties than annealed components. The same are explained in Table 4.7.1. However, normalizing takes less time and is more convenient and economical than annealing and hence is a more common heat treatment in industries. Normalizing is used for high-carbon (hypereutectoid) steels to eliminate the cementite network that may develop upon slow cooling in the temperature range from point Acm to point A1. Normalizing is also used to relieve internal stresses induced by heat treating, welding, casting, forging, forming, or machining. Normalizing also improves the ductility without reducing the hardness and strength.

Purpose of annealing and normalizing is to obtain the following:

ANNEALED	NORMALISED
Less hardness, tensile strength and toughness	Slightly more hardness, tensile strength and toughness
Pearlite is coarse	Pearlite is fine
Grain size distribution is more uniform	Grain size distribution is less uniform
Internal stress is less	Internal stress is more

Martempering and nitriding processes.

Martempering (marquenching)

Martempering process overcomes the limitation of the conventional hardening process. Figure 1 depicts the martempering process. This process follows interrupted quenching operation. In other words, the cooling is stopped at a point above the martensite transformation region to allow sufficient time for the center to cool to the temperature as the surface. Further cooling is continued through the martensite region, followed by the usual tempering. In this process, the transformation of austenite to martensite takes place at the same time throughout the structure of the metal part.

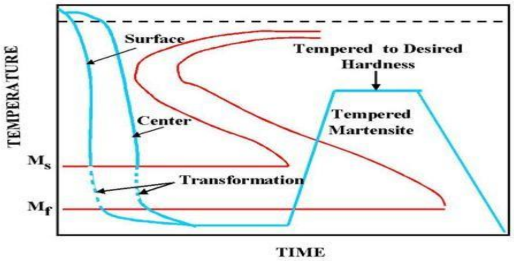


FIGURE 1 Martempering (marquenching)

Nitriding

Nitriding is a thermo chemical case hardening process used to increase wear resistance, surface hardness and fatigue life by dissolution of nitrogen and hard nitride precipitations

Nitriding is carried out in the ferritic region. No phase change occurs after nitriding. The part to be nitrided should posses the required core properties prior to nitriding. During nitriding, pure ammonia decomposes to yield nitrogen which enters the steel. The solubility of nitrogen in ferrite is small. Most of the nitrogen, that enters the steel, forms hard nitrides (e.g., Fe3N). The temperature of nitriding is 500-590o C. The time for a case depth of 0.02 mm is about 2 hr. In addition to providing outstanding wear resistance, the nitride layer increases the resistance of carbon steel to corrosion in moist atmospheres.

Nitriding is most effective when applied to the range of steels containing nitride-forming elements such as chromium, molybdenum, vanadium and aluminum. The process is also applicable to tool steels such as hot-work, cold-work and mould steels. A low temperature application is nitriding of spring steels to prolong the fatigue life of springs for automotive use. In general, all ferrous materials can be gas nitrided up to 5% chromium. For higher contents of alloying elements and for gas nitriding of stainless steel, plasma nitriding might be considered. Gas nitriding of sintered steels with low density is not recommended.

Nitriding Process

Nitriding is a low temperature (typically 520°C/970°F), low distortion "thermochemical" heat treatment process carried out to enhance the surface properties of finished or near finished ferrous components. If a carbon spending gas is added, the process is called gas nitrocarburising. The layer usually consists of two zones – the compound layer (white layer) which can be a cubic or hexagonal nitride and the diffusion layer below with dissolved nitrogen and hard nitride precipitations. The compound layer on the surface of the parts is responsible for the major benefit of high resistance to wear, scuffing, galling and seizure. The diffusion layer contributes improved fatigue strength and works as a support for the hard compound layer. By controlling and adjusting the process atmosphere, the constitution of the layer can be influenced from thin compound layers for fatigue strength improvement to thick nitrogen and carbon rich compound layers in case of gaseous nitrocarburising and post oxidation if good wear and corrosion resistance is desired.

Merits of Nitriding:

Favored for components that are subjected to heavy loading, nitriding imparts a high surface hardness which promotes high resistance to wear, scuffing, galling and seizure. Fatigue strength is increased mainly by the development of surface compressive stresses. The wide range of possible temperatures and case depths, which allow adjustment of different properties of the treated parts, give gas nitriding a broad field of applications

Applications

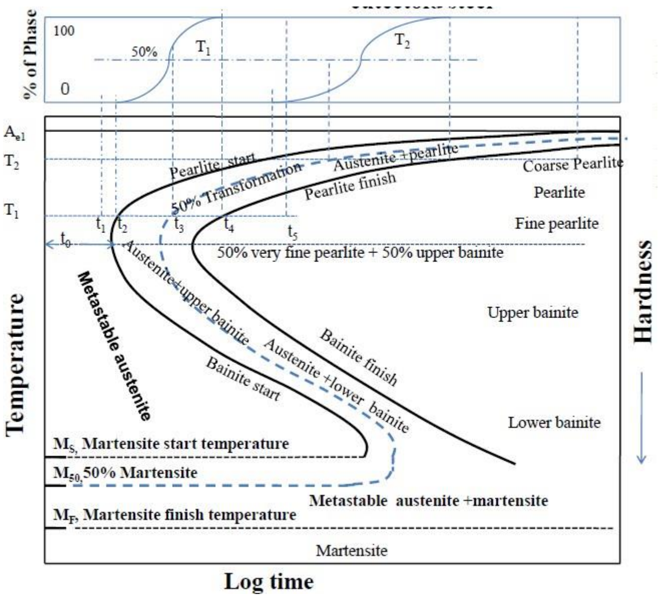
Applications include gears, crankshafts, camshafts, cam followers, valve parts, springs, extrusion screws, die-cast tooling, forging dies, aluminum-extrusion dies, injectors and plastic-moulds.

TTT diagram for 0.8% carbon steel and its isothermal transformations

There are two main types of transformation diagram that are helpful in selecting the optimum steel and processing route to achieve a given set of properties. These are time-temperature transformation (TTT) and continuous cooling transformation (CCT) diagrams.

Time-temperature transformation (TTT) diagrams measure the rate of transformation at a constant temperature. In other words a sample is austenitised and then cooled rapidly to a lower temperature and held at that temperature whilst the rate of transformation is measured, for example by dilatometer. Obviously a large number of experiments are required to build up a complete TTT diagram.

TTT diagram stands for “time-temperature-transformation” diagram. It is also called isothermal transformation diagram



At close to Ae1temperature, coarse pearlite forms at close to Ae1temperature due to low driving force or nucleation rate. At higher under coolings or lower temperature finer pearlite forms.

At the nose of TTT diagram very fine pearlite forms

Close to the eutectoid temperature, the under cooling is low so that the driving force for the transformation is small .However, as the underr cooling increases transformation accelerates until the maximum rate is obtained at the "nose" of the curve . Below this temperature the driving force for transformation continues to increase but there action is no wimped by slow diffusion. This is why TTT curve takes on a "C" shape with most rapid overall transformation at some intermediate temperature.

Pearlitic transformation is reconstructive. At a given temperature (sayT1) the transformation starts after an incubation period (t2,atT1) Locus of t2 for different for different temperature is called transformation start line. After 50% transformation locus of tha ttime (t3atT1) for different temperatures is called 50% transformation line. While transformation completes that time (t4atT1) is called transformation finish, locus of that is called transformation finish line. Therefore TTT diagram consists of different t percentage lines of which 1%,50% and99% transformation lines are shown in the diagram. At high temperature while under clooling is low form coarsepearlite. A the nose temperature fine pearlite and upperbainite form simultaneously though the mechanisms of their formation are entirely different.

Upper bainite forms at high temperature close to the nose of TTT diagram while the lower bainite forms at lower temperature but above MS temperature.

On cooling of metastable austenite1% martensite forms about 230°C. The transformation is athermal in nature.i.e. amount of transformation is time independent (characteristic amount of transformation completes in a very shor ttime) but function of temperature alone. This temperature is called the martensite start temperature or MS.

Below Ms While metastable austenite is quenched at different temperature amount of martensite increases with decreasing temperature and does not change with time.

flame hardening and induction hardening

Flame hardening:

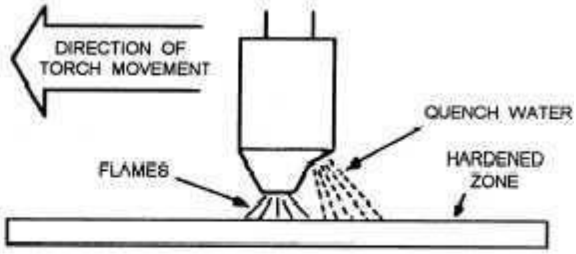


FIG: Flame hardening

Flame hardening is surface hardening process. Heat is applied to the part being hardened, using an oxy- acetylene (or similar gas) flame on the surface of the steel being hardened and heating the surface above the upper critical temperature before quenching the steel in a spray of water. The result is a hard surface layer ranging from 0.050" to 0.250" deep. As with induction hardening, the steel component must have sufficient carbon (greater than 0.35%). The composition of the steel is not changed; therefore core mechanical properties are unaffected. Flame hardening produces results similar to conventional hardening processes but with less hardness penetration. Applications for flame hardening are similar to those for induction hardening, although an advantage of flame hardening is the ability to harden flat surfaces. Flat wear plates and knives can be selectively hardened using this process.

Induction Hardening

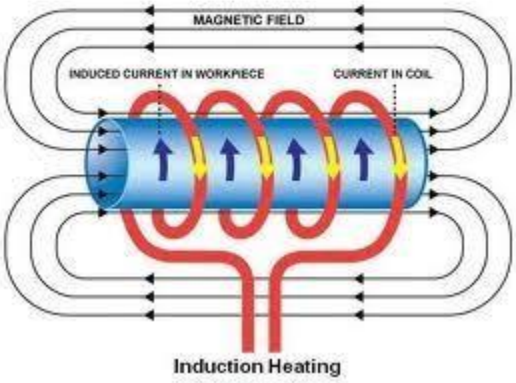


FIG: Induction hardening

Induction hardening is a process used for the surface hardening of steel and other alloy components. The parts to be heat treated is placed inside water cooled copper coil and then heated above their transformation temperature by applying an alternating current to the coil. The alternating current in the coil induces an alternating magnetic field within the work piece, which if made from steel, caused the outer surface of the part to heat to a temperature above the transformation range. Parts are held at that temperature until the appropriate depth of hardening has been achieved, and then quenched in oil, or another media, depending upon the steel type and hardness desired. The core of the component remains unaffected by the treatment and its physical properties are those of the bar from which it was machined or preheat treated. The hardness of the case can be HRC 37 - 58. Carbon and alloy steels with a carbon content in the range 0.40 - 0.45% are most suitable for this process. In some cases, parts made from alloy steels for steel and paper mill rolls, are first carburized to a required case depth and slow cooled, and then induction hardened. This is to realize the benefit of relatively high core mechanical properties, and surface hardness greater than HRC 60, which provides excellent protection.

While induction hardening is most commonly used for steel parts, other alloys such as copper alloys, which is solution treated and tempered, may be induction hardened as well. Applications include hardening bearing races, gears, pinion shafts, crane (and other) wheels and treads, and threaded pipe used for oil patch drilling.

Austempering

This process is also used to overcome the limitation of the conventional hardening process. Figure 2 depicts the austempering process. Here the quench is interrupted at a higher temperature than for martempering to allow the metal at the center of the part to reach the same temperature as the surface. By maintaining that temperature, both the center and surface are allowed to transform to bainite and are then cooled to room temperature. Austempering causes less distortion and cracking than that in the case of martempering and avoids the tempering operation. Austempering also improves the impact toughness and the ductility of the metal than that in the case of martempering and conventional hardening.

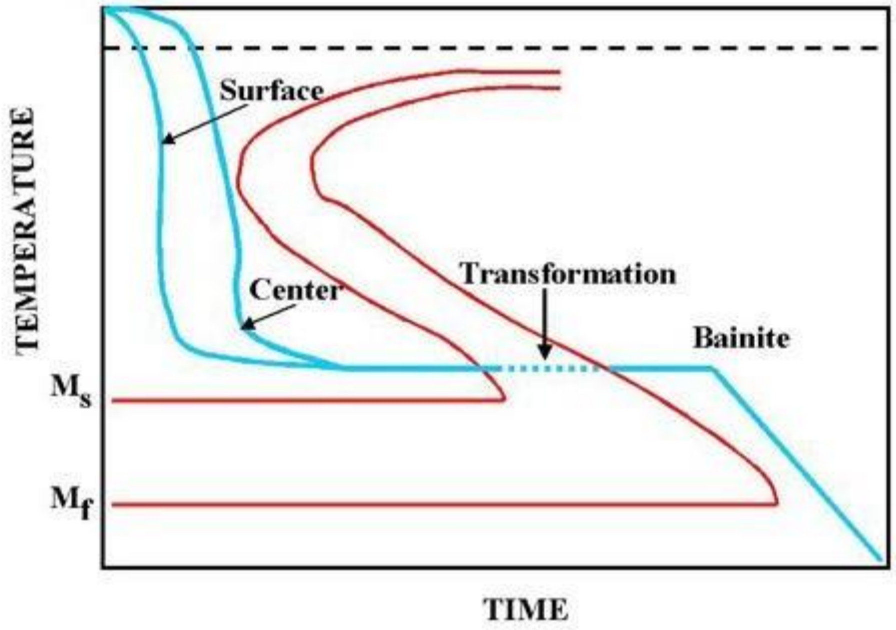


FIGURE 2 Austempering

Hardenability of steels.

Hardenability:

Hardenability is defined as the relative ability of steel to be hardened by quenching and it determines the depth and distribution of hardness across the cross section.

Jominy End Quench Test:

The Jominy Test involves heating a test piece from the steel (25mm diameter and 100mm long) to an austenitising temperature and quenching from one end with a controlled and standardised jet of water.

Procedure:

Sample steel machined to the shape as shown in Figure 1. It is a cylindirical bar with a 25 mm. diameter and 100 mm. length.

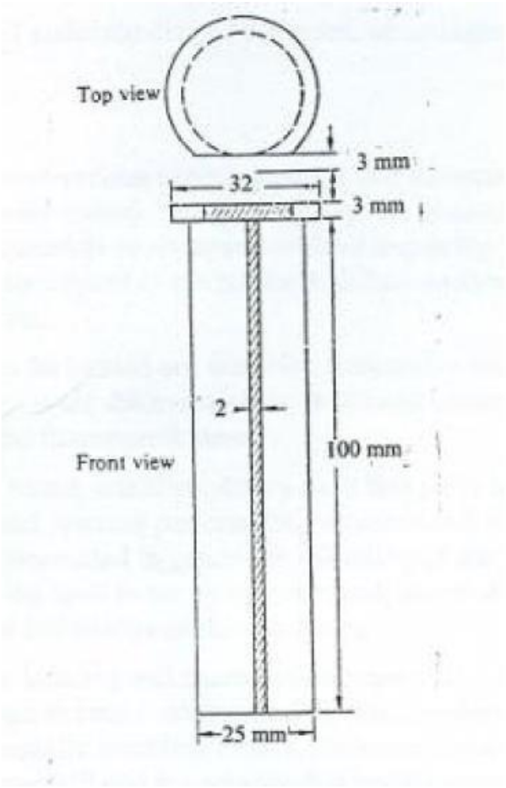


FIGURE 1:SPECIMEN

The specimen is placed in the furnace at 900 0 C for about 1 /2 hour. The water flow rate is adjusted so that the water column is approximately the distance 50 mm above the end of the pipe, when water is flowing freely. After the sample has been austenitized, it is removed from the furnace and placed directly into the quenching apparatus. A jet of water is quickly splashed at one end of the specimen as shown in figure 2.

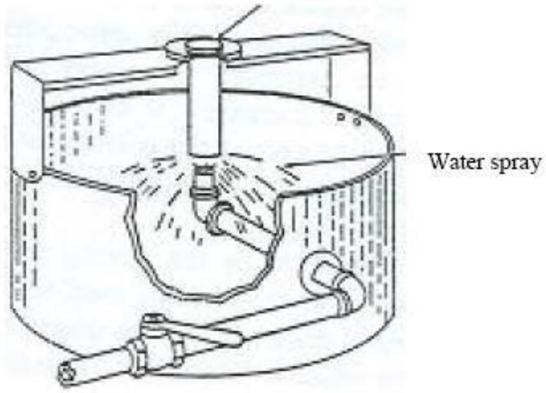


Figure 2 Jominy End Quench Test apparatus

Hardenability Curves:

After the entire sample has cooled to room temperature, the scale oxidation is removed; two opposite and flat parallel surfaces are ground along the length of the bar. Rockwell C hardness measurements are then made every 2 mm and these readings are recorded as in figure 3.

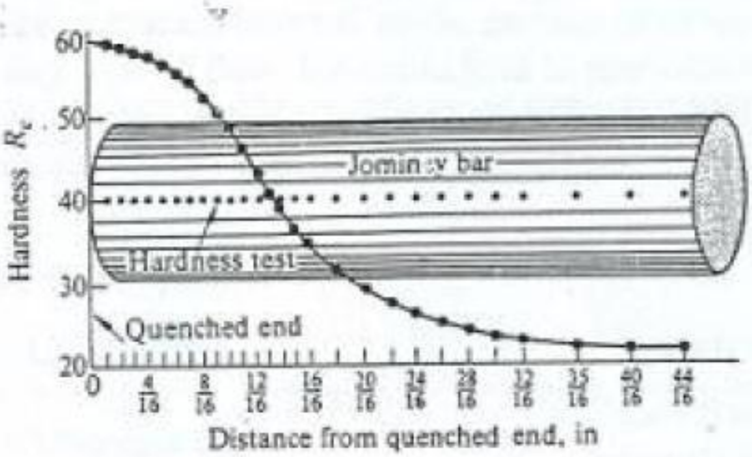


Fig.3 Position of hardness test points along the bar.

Cyaniding process:

Cyaniding process involves the diffusion of both carbon and nitrogen into the surface of the steel. This process is used for low carbon steels (0.2%C) and is similar to liquid carburizing because of the use of cyanide salt bath.

The steel is immersed in a molten salt bath of sodium cyanide heated by immersed electrodes. The concentrated of sodium cyanide varies between 25% to 90%. The most commonly used concentration is 30%. The bath is heated at a temperature between 800 and 870°C.

The basic reactions in the bath are

i. **Molten cyanide decomposes in the presence of air at the surface of the bath to produce sodium cyanate.**

$$\mathbf{2NaCN+O_2 \rightarrow 2NaCNO}$$

ii. **The sodium cyanate further dissociates to liberate carbon and nitrogen.**

$$\mathbf{4NaCNO \rightarrow Na_2CO_3+2NaCN+CO+2(N)}$$

$$\mathbf{2CO \rightarrow CO_2+(C)}$$

Carbon and nitrogen so formed are absorbed at the surface of the steel. After cyaniding, the pieces are quenched directly into oil or water.

The case depth obtained is in the range of 0.025 -0.25mm and the surface hardness is up to 65HRC. The process is particularly useful for parts such as screws, small gears, nuts and bolts etc.

Advantages:

This process is less time consuming.

Disadvantages:

i) Since cyanides are very poisonous, care is required
ii) This process is not suitable for parts which are subjected to shock, fatigue and impact because nitrogen addition has an adverse effect on such properties of steel.

MCQ

Questions	opt1	opt2	opt3	opt4	answer
The Temperature at which the hypoeutectoid steel are heated for full annealing is	between 723C and 910 °C	above 910 °C	below 723 °C	none of these	between 723C and 910 °C
The resulting structure of hypoeutectoid steel after full annealing is	pearlite with cementite	pearlite with ferrite	ferrite with cementite	ferrite with martensite	pearlite with ferrite
The resulting structure of hyper eutectoid steel after full annealing is	pearlite with ferrite	ferrite with cementite	pearlite with cementite	none of these	pearlite with cementite
___________provides a fine grain structure	full annealing	normalizing	tempering	hardening	normalizing
The low temperature tempering is performed in the temperature range from	350 to 450 °C	150 to 250 °C	500 to 600 °C	none of these	150 to 250 °C
The tempering which is performed in the temperature range from 350 to 450 °C is known as	low temperature tempering	medium temperature tempering	high temperature tempering	none of these	medium temperature tempering
The structure formed after normalizing for hypo eutectoid steel are	ferrite and pearlite	ferrite and cementite	austentite and cementite	pearlite and cementite	ferrite and pearlite
The structure formed after normalizing for hypereutectoid steels are	Ferrite and pearlite	Ferrite and cementite	Ferrite and cementite	Pearlite and cementite	Pearlite and cementite
The structure formed after austempering is	Bainite	Pearlite	Cementite	Ferrite	Bainite
Selecting of temperature for heat treatment is based on	Fe – Fe3C phase diagram	TTT diagram	CCT diagram	S – curves	Fe – Fe3C phase diagram
TTT diagram is also called as	isothermal transformation	S curve	. C Curve	bains curve	isothermal transformation
Assumption in TTT diagram	Temperature is constant during	Time is constant during	Temperature is constant in	Time is constant in	Temperature is constant

	transformation	transformation	equilibrium	equilibrium	during transformation
In CCT diaram very slow cooling rate results in	coarse pearlite	fine pearlite	pearlite and cementite	granular cementite	coarse pearlite
In CCT diagram more rapid cooling results in	Coarse to fine pearlite	fine to coarse pearlite	bainite	martensite	Coarse to fine pearlite
In CCT diagram if water is quenching medium then the resulting microstructure is	martensite	bainite	fine bainite	leduburite.	martensite
Critical cooling rate results in slowest rate of cooling of austenite to	100% martensite	50% martensite and 50% pearlite	25% martensite and 75% pearlite	martensite and bainite	100% martensite
Hardening results with	formation of cementite	formation of martensite	formation of bainite	decomposition of austentite	formation of martensite
Corrosion resistance of steel is increased by addition of	vanadium, aluminium	tungsten, molybdenum	chromium and nickel	zinc	chromium and nickel
Cyaniding is the process of	Hardening	Surface hardening	Coating	none of these	Surface hardening
Induction hardening is the process of	hardening surface of workpiece to obtain hard and wear resistant surface	heating and cooling rapidly	increasing different hardness throughout	hardening core	hardening surface of workpiece to obtain hard and wear resistant surface
Process of austempering results in	formation of bainite structure	carburized structure	martenistic structure	relieving stresses throughout a component	formation of bainite structure

2 marks

1. Define Normalizing and Hardening process.
    - Normalizing is a heat treatment obtained by austenizing and air cooling to produce a fine pearlite structure.
    - Hardening is heat treatment process it which increases the hardness by quenching.
2. Explain carburizing and nitriding.
    - Carburizing is a process in which carbon atoms are introduced on to the surface of low carbon steels to produce a hard case of surface while the interior or core remains soft.
    - Nitriding is defined as the process of introducing both nitrogen and carbon to obtain hard surface of the steel component.
3. What is the use of the isothermal transformation diagram?

    It's a plot of temperature versus the logarithm of time for a steel alloy and composition it is used to determine the transformation begins and end for an isothermal constant temperature (heat treatment)of a previously austenitized alloy.
4. Name the various method of heat treatment of steel.

    a. annealing b. nitrining c. carburizing
5. Explain the term Stress relief annealing and Spheroidizing.
    - Stress relief annealing is the heat treat to remove residual stress caused by machining, grinding, non cooling of metal, phase transformation with different densities.
    - Spheroidizing means Medium & High carbon steels are changed their grain structure from coarse pearlite to spherodite structure to get softness and ductility for easy machining.
6. Differentiate between Tempering and Maraging.
    - Tempering is the process of heating martensite steel to250' c to 650 c' to get the

      property of ductility & toughness.
    - Maraging steels are low carbon high alloy steels, which is very high strength material that can be hardened to obtain tensile strengths up to 1900MPA. NI-18%, CO-7% and small amount of other elements such as titanium the carbon content is low less than 0.05%
7. Define the term heat treatment.

    Heat treatment may be defined as an operation or combination of operations involving heating and cooling of a metal in solid state to obtain desirable properties
8. What are the purposes of processing heat treatments?

    To relieve internal stresses, to improve machinability, to refin grain size, to soften the metal.
9. Explain the purpose of annealing.

    To remove stresses, To induce softness, To refine grain structure, To remove gases.

10. Define quenching stages for quenching.

    Quenching refers accelerated cooling

    - Vapour –jacket stage
    - Vapour-transport cooling stage
    - Liquid cooling stage

11. What is a CCT diagram?

    The CCT diagram is a plot of temperature versus the logarithm of time for steel alloy of definite composition. It is used to indicate when transformations occur as the initially

    austenitised material is continuously cooled at a specified rate. In addition, it is also used to predict the final microstructure and mechanical characteristics.

12. In what ways flame hardening differs from induction hardening.

    The mechanism and purpose of induction hardening are the same as for flame hardening. The main difference is that induction hardening the source of heat input is an induced electric current instead of using flame.

13. List some of the surface hardening techniques employed for altering surface chemistry.

    - Diffusion methods

    (a) Carburizing (b) Nitriding (c) Cyaniding (d) Carbonitriding

    - Thermal methods

    (a) Flame hardening (b) Induction hardening

14. What do you meant by the term case hardening?

    In many applications, it is desirable that the surface of the components should have high hardness, while the inside or core should be soft. The treatments given to steels to achieve this are called surface heat treatments or surface hardening

15. Case carburizing treatment is not generally carried out for medium carbon steels. Why?

    The carburizing process is a diffusion treatment process. For diffusion take place the host metal must have a low concentration of the diffusing species and there must be a significant concentration of the diffusing species at the surface in the host metal. Since the medium carbon steels lack the above said criteria, they are not generally carburized.

16. In what ways cyaniding differs from carburizing.

    The salt both compositions for cyaniding give a case high in nitrogen, whereas carburizing gives a case rich in carbon

17. Name and explain any one subcritical case hardening treatment.

    Nitriding is a subcritical case hardening treatment. Nitriding is a process of introducing nitrogen atoms to obtain hard surface of steel components

18. Mention few applications of induction hardening.

The induction hardening is employed for hardening he surfaces of gears, tools, wrist pins, crank shaft bearings, machine tool ways and pump shafts.

19. List the advantages of austempering.

    Improved ductility, increased impact strength and toughness, decreased distortion of the quenched metal, less danger of quenching cracks.

20. What is Flame hardening?

    Flame hardening is case hardening consisting of heating the selected areas of steel into the austenite range with an oxyacetylene or oxyhydrogen flame and immediately quenching it to form martensite.

21. Mention the different methods of heat treatment.

    Annealing, Tempering, Hardening, Austempering, Martempering, Normalizing and spheriodising are some of the heat treatment of metals

22. Describe the factors affecting mechanical properties of metals.

    1. Grain Size - Smaller grain size posses higher strength.
    2. Heat treatment

23. What is T-T-T diagram?

    T-T-T diagram is also called isothermal transformation diagram [Temperature-Time – Transformation]. It is a plot of temperature verses the logarithm of time for a steel alloy of definite composition. It is used to determine when transformations begin and end for an isothermal [constant thermal] heat treatment of a previously austenitized alloy.

24. Why has gas carburizing largely replaced other methods of carburizing in mass production operations?

    Because of the following reasons the gas carburizing replaces the other methods.

    - Less time is required than pack carburizing.
    - Less floor space is required.
    - Cleaner surroundings,
    - Closer quality control.

25. Explain sub-zero treatment of steel.

    Whenever the steel is hardened some amount of austenite is always retained by it. This results in the reduction of hardness, thermal conductivity and wears resistance. The sub- zero treatment of harden steel reduces the retained austenite. In this process the hardened steel part is cooled to sub-zero temperatures. [between -30 ^{0}C to -120^{0}C]

26. What is “Patenting”?

    A special application of isothermal hardening is called patenting and is used for steel wire.. Steel wire with 0.40 – 1.10% carbon is quenched from the temperature in a bath of molten lead to about 4000 C to 5000 C. A structure with possess good ductility in addition to a hardness.

27. Define tempering.

    Tempering is the process re-heating the hardened steel to some temperature below its critical temperature in order to impart toughness and to reduce brittleness. This reduces the internal stresses developed during hardening.

28. What is the basic difference between cyaniding and carbo-nitriding?

CYANIDING	CARBO-NITRIDING
Ferrous materials heated above the lower transformation range in a molten salt NaCN, Na_2CO_3 &	Ferrous metal is heated above the lower transformation range in a gaseous atmosphere of suitable composition.

29. Explain the two types of surface hardening methods.

    The two types of surface hardening methods are.

    1. Diffusion methods:

       These methods involve heating the entire sample to a particular temperature, in a suitable atmosphere, so that absorption of foreign atoms and consequent diffusion takes place. This results in hardening of surface of few hundred microns depth.

    2. Non-diffusion methods:

       These methods involve hardening the surface by heating and then subsequent cooling.

30. What is laser surface hardening?

    Use of high power laser to harden the surface of a material is known as laser surface hardening. The metal (Steel) is heated to higher temperatures and quenched in water.

31. Explain annealing. Classify it.

    Steels of 0.3 to 0.6% C content is heated 300 C to 40oC above upper critical Temperature line and cooled in a furnace atmosphere. This heat treatment relives the internal stresses and improves the ductility of steels.

    1. Full Annealing
    2. Process Annealing
    3. Spheroidisation Annealing
    4. Stress Relief Annealing

32. What is re-crystallization Temperature?

    The minimum temperature at which new crystals are formed with in the materials while heating.

33. Define Spherodizing Annealing. What is the main Advantage of Spherodizing

    The steels are heated to a temperature just above the critical and cool very slowly (About 60C per hour) through the critical range. This causes all carbides in the steels at agglomerate in the form of globus or spheroids. This spheroids improves the machinablity and surface finish of the machined parts.

34. Explain CCR.

    The minimum cooling rate at which all of the austenite is super cooled , and is transformed into martensite is called CRITICAL COOLING RATE. The magnitude of critical cooling rate depends on the stability of the austenite. The higher the Stability of the austenite, the less the critical cooling rate. Eutectoid steels have the lowest critical cooling rate.

35. What is Flame Hardening? Where it is used?

    It is a process of surface hardening by which steel or cast iron is heated to high temperature by a gas flame and then almost immediately quenched.This process of hardening is used for hardening of wheel teeth and lathe bed.

36. Define Hardenablity

    Hardenability refers the ability to develop its maximum hardness when subjected to the normal hardening heating and cooling cycle. Maximum hardness obtainable with steel of given composition

37. Write the factors affecting hardenablity of materials.

    Carbon content, Structure of the material- Grain size, Homogeneity of composition, Medium and process of quenching, Heating rate time,

38. What is Austempering?

    Heat the steel to the austenite temperature state then quenching it in a bath held above the temperature at which martensite begins to form. The steel then remains at that temperature until the austenite is completely transformed into banite, after which it is allowed to cool.

39. Enumerate Martempering?

    Martempering is a hardening treatment that consists of heating a steel to its austenite steel and then quenching it to a temperature just above which martensite starts to form. The cooling rate must be faster than the critical cooling rate. The steel is then held at that temperature for sufficiently long time for the entire piece of steel to come to the same temperature, without any transformation to banite occurring. It is then cooled in air to change the austenite to martensite.

14 marks

1. Explain the difference between TTT diagram and iron –carbon equilibrium diagram.
2. Describe why are TTT diagrams usually not applicable to industrial engineering practices?
3. What are the differences between surface hardening by diffusion methods and thermal methods?
4. Define the following surface hardening process:

   (a) arburishing (b) Nitriding (c) Cyaniding (d) Carbonitriding.

   (e) Difference between pack carburizing and gas carburizing?

5. What do you understand by hardening of steel? Discuss the reason why martensite is very hard. Also discuss the various characteristics of martensite transformation.
6. Draw a neat sketch of the TTT diagram for eutectoid steel and label the regions. Mark the difference products formed on this diagram.
7. What is a CCT diagram? Describe various cooling curves on CCT diagrams. How such curves are drawn? Write short notes on critical cooling rate.
8. What is meant by carburizing of steels? Briefly explain the various types of carburizing.
9. Explain the process of nitriding. List and discuss the advantages of nitriding over carburizing.
10. Give a detailed account on annealing, normalizing, austempering and case hardening.
11. Distinguish between annealing and normalizing.
12. Explain how surface hardening is achieved using flame hardening.
13. Define the types of annealing Process and explain it?
14. Demonstrate Isothermal Transformation diagram (TTT) or (c-curve) or (s-curve)
15. Brief about tempering process and explain CCT diagram.
16. Enumerate Martempering and Austempering.
17. Explain the following case hardening process: i) Carburising ii) Carbo-nitriding
    iii) Induction hardening iv) Nitriding v) Flame hardening

UNIT III

Classifications of Stainless Steel

Stainless steels are commonly divided into five groups, depending on the specific amounts of alloying elements, which control the microstructure of the alloy.

Austenitic :

Austenitic stainless steels are the most weldable of the stainlesses and can be divided rather loosely into three groups: common chromium-nickel (300 series), manganese-chromium-nickel-nitrogen (200 series) and specialty alloys. Austenitic is the most popular stainless steel group and is used for numerous industrial and consumer applications, such as in chemical plants, power plants, food processing and dairy equipment. Austenitic stainless steels have a face-centered cubic structure. Though generally very weldable, some grades can be prone to sensitization of the weld heat-affected zone and weld metal hot cracking.

Ferritic :

Ferritic stainless steel consists of iron-chromium alloys with body-centered cubic crystal structures. They can have good ductility and formability, but high-temperature strengths are relatively poor when compared to austenitic grades. Some ferritic stainlesses (such as types 409 and 405) used, for example, in mufflers, exhaust systems, kitchen counters and sinks, cost less than other stainless steels. Other more highly alloyed steels low in C and N (such as types 444 and 261) are more costly, but are highly resistant to chlorides.

Martensitic :

Martensitic stainless steels, such as types 403, 410, 410NiMo and 420, are similar in composition to the ferrite group, but contain a balance of C and Ni vs. Cr and Mo; hence, austenite at high temperatures transforms to martensite at low temperatures. Like ferrite, they also have a body-centered cubic crystal structure in the hardened condition. The carbon content of these hardenable steels affects forming and welding. To obtain useful properties and prevent cracking, the weldable martensitics usually require preheating and postweld heat treatment.

Duplex:

Primarily used in chemical plants and piping applications, the duplex stainless steels are developing rapidly today and have a microstructure of approximately equal amounts of ferrite and austenite. Duplex stainless steels typically contain approximately 22-25% chromium and 5% nickel with molybdenum and nitrogen. Although duplex and some austenitics do have similar alloying elements, duplexes have higher yield strength and greater stress corrosion cracking resistance to chloride than austenitic stainless steels.

Precipitation Hardening:

Precipitation-hardening stainless steels are chromium-nickel stainlesses, which contain alloying additions such as aluminum, copper or titanium that allow them to be hardened by a solution and aging heat treatment. They can be either austenitic or martensitic in the aged condition. Precipitation- hardening stainless steels are grouped into three types: martensitic, semiaustenitic and austenitic. The martensitic (such as Type 630) and semiaustenitic (such as Type 631) can provide higher strength than the austenitic (such as Type 660, also known as A286).

Selecting Stainless Steel :

The selection of a particular type of stainless steel will depend on what requirements a particular application poses. Environment, expected part life and extent of acceptable corrosion all help determine what type of stainless to use. In most cases, the primary factor is corrosion resistance, followed by tarnish and oxidation resistance. Other factors include the ability to withstand pitting, crevice corrosion and intergranular attack. The austenitic/higher chromium stainless steels, usually required in very high or very low temperatures, are generally more corrosion resistant than the lower chromium ferritic or martensitic stainlesses.

Most stainless steels are considered to have good weldability. It is important to make sure joint surfaces and any filler metal be kept free from oxide, organic material or other contamination.

W - Water hardened tool steels: (W-AISI/SAE Grade)

W-type tool steel gets its name from its defining property of having to be water quenched. W-grade steel is essentially high carbon plain-carbon steel. This type of tool steel is the most commonly used tool steel because of its low cost compared to other tool steels. They work well for small parts and applications where high temperatures are not encountered; above 150 °C (302 °F) it begins to soften to a noticeable degree.Hardenability is low so W-grade tool steels must be quenched in water. These steels can attain high hardness (above HRC 66) and are rather brittle compared to other tool steels. W steels are still sold, especially for springs, but are much less widely used than they were in the 19th and early 20th centuries. This is partly because W steels warp and crack much more in quench than oil-quenched or air hardening steels.

The toughness of W-type tool steels are increased by alloying with manganese, silicon and molybdenum. Up to 0.20% of vanadium is used to retain fine grain sizes during heat treating.

Typical applications for various carbon compositions are:

- 0.60–0.75% carbon: machine parts, chisels, setscrews; properties include medium hardness with good toughness and shock resistance.
- 0.76–0.90% carbon: forging dies, hammers, and sledges.
- 0.91–1.10% carbon: general purpose tooling applications that require a good balance of wear resistance and toughness, such as rasps, drills, cutters, and shear blades.
- 1.11–1.30% carbon: files, small drills, lathe tools, razor blades, and other light-duty applications where more wear resistance is required without great toughness. Steel of about 0.8 % C gets as hard as steel with more carbon, but the free iron carbide particles in 1% or 1.25% carbon steel make it hold an edge better. However, the fine edge probably rusts off faster than it wears off, if it is used to cut acidic or salty materials.

Properties: low cost, very hard, brittle, relatively low harden ability, suitable for small parts working at not elevated temperatures.

S – Shock resistant tool steels: (S-AISI/SAE Grade)

S-type tool steels are designed to resist shock at both low and high temperatures. A low carbon content is required for the necessary toughness (approximately 0.5% carbon). Carbide-forming alloys provide the necessary abrasion resistance, hardenability, and hot-working characteristics. This family of steels displays very high impact toughness and relatively low abrasion resistance and can attain relatively high hardness (HRC 58/60). This type of steel is used in applications such as the production of jackhammer bits. In the US, toughness usually derives from 1 to 2% silicon and 0.5-1% molybdenum content. In Europe, shock steels often contain .5-.6 % carbon and around 3% nickel. 1.75% to 2.75% nickel is still used in some shock resisting and high strength low alloy steels (HSLA), such as L6, 4340, and Swedish saw steel, but it is relatively expensive.

Applications: tools experiencing hot or cold impact.

Properties: combine high toughness with good wear resistance.

3.Explain in detail maraging steels and high speed steels.

Maraging steels:

Maraging steels are carbon free iron-nickel alloys with additions of cobalt, molybdenum, titanium and aluminium. The term maraging is derived from the strengthening mechanism, which is transforming the alloy to martensite with subsequent age hardening.

Air cooling the alloy to room temperature from 820°C creates a soft iron nickel martensite, which contains molybdenum and cobalt in supersaturated solid solution. Tempering at 480 to 500°C results in strong hardening due to the precipitation of a number of intermetallic phases, including, nickel-molybdenum, iron-molybdenum and iron-nickel varieties.

Properties:

1. With yield strength between 1400 and 2400 MPa maraging steels belong to the category of ultra-high-strength materials.
2. Has high strength
3. Excellent toughness properties
4. Good weldability.

Typical applications areas include:

- Aerospace, e.g. undercarriage parts and wing fittings,
- Tooling & machinery , e.g. extrusion press rams and mandrels in tube production, gears
- Ordnance components and fasteners.

High Speed Steels:

One of the earliest applications of molybdenum was as an efficient and cost effective replacement for tungsten in tool steels and high-speed steels. The atomic weight of molybdenum is roughly half that of tungsten and therefore 1% Mo is roughly equivalent to 2% tungsten. Because these highly alloyed steels are used in the working, cutting and forming of metal components, they must possess high hardness and strength, combined with good toughness, over a broad temperature range.

When tool steels contain a combination of more than 7% molybdenum, tungsten and vanadium, and more than 0.60% carbon, they are referred to as high speed steelss.

Additions of 5-10% Mo effectively maximize the hardness and toughness of high-speed steels and maintain these properties at the high temperatures generated when cutting metals. Molybdenum provides another advantage: at high temperature, steels soften and become embrittled if the primary carbides of iron and chromium grow rapidly in size. Molybdenum, especially in combination with vanadium, minimizes this by causing the carbides to reform as tiny secondary carbides which are more stable at high temperatures.

Applications:

The largest use of high-speed steels is in the manufacture of various cutting tools: drills, milling cutters, gear cutters, saw blades, etc.

The exceptional high temperature wear properties of molybdenum-containing high-speed steels are ideal for new applications such as automobile valve inserts and cam-rings.

Classification of brass

The brasses are classified according to the zinc % into two groups

(i) Red α brasses (5-20% zinc)

(ii) Yellow α brass (20-36% zinc)

(iii) α β brass (34-46% zinc)

(i) Red α brasses (5-20% Zinc)

Alpha brasses are malleable, can be worked cold, and are used in pressing, forging, or similar applications. They contain only one phase, with face-centered cubic crystal structure.The following are the various types of Red α brasses.

(a) Gilding metal- Gilding metal is a copper alloy, a brass, comprising 95% copper and 5% zinc. Gilding metal is used for various purposes, including the jackets of bullets, driving bands on artillery shells, coins and base for gold plating.
(b) Commercial brass- Commercial brass contains 90% Cu and 10% Zn.Has excellent cold and hot working. It is used for jewellery and grill works.
(c) Red brass- It contains 85% Cu and 15% Zn.It has good corrosion resistance and so used for heat exchangers, weather stripping and electrical sockets.
(d) Low brass- It contains 80% Cu and 20% Zn.It is used for musical instruments and flexible hoses.

(ii) Yellow α brass (20-36% Zinc)

Yellow α brasses contains 20-36% Zinc.Itioncludes the following types
(a) Cartridge brass-Cartridge brass is a 30% zinc brass with good cold working properties. Used for ammunition cases.
(b) Yellow brass- Yellow brass is an American term for 33% zinc brass. It is used as reflectors, fasteners and springs.
(c) Admiralty brass- Admiralty brass contains 30% zinc, and 1% tin which inhibits dezincification in many environments has good strength and corrosion resistance and so suitable for steam power plants.
(d) Aluminium brass -Aluminium brass contains aluminium, which improves its corrosion resistance. It is used for seawater service and also in Euro coins (Nordic gold).

(iii) α β brass (34-46% zinc):

α β brass also called duplex brasses. Suited for hot working It contains both α and β' phase; the β'-phase is body-centered cubic and is harder and stronger than α. Alpha-beta brasses are usually worked hot. The following are the various types of α β brass

(a) Muntz metal is about 60% copper, 40% zinc and a trace of iron, used as a lining on boats.

(b) Naval brass, similar to admiralty brass, is 40% zinc and 1% tin.

(c) Leaded brass is an alpha-beta brass with an addition of lead. It has excellent machinability.

(d) High brass contains 65% copper and 35% zinc, has a high tensile strength and is used for springs, screws, and rivets.

MCQ

Questions	opt1	opt2	opt3	opt4	answer
1. The purpose of alloying is to	To increase harden ability.	To improve strength at elevated temperatures.	To increase corrosion and oxidation resistance.	All of these	All of these
2. The general effects of alloying in steel are	Carbide formation.	Solid solution formation.	Shifting of critical temperature.	All of these	All of these
3. The effect of adding Boron in steel is	It improves wear resistance.	It improves hardenability.	It improves hot hardness.	It improves machinability.	It improves hardenability.
4. The effect of adding Lead in steel is	It improves wear resistance.	It improves hardenability.	It improves hot hardness.	It improves machinability.	It improves machinability.
5. The effect of adding Cobalt in steel is	It improves wear resistance.	It improves hardenability.	It improves hot hardness.	It improves machinability.	It improves hot hardness.
6. The effect of adding Chromium in steel is	Improves wear, corrosion resistance and hardenability.	It improves toughness.	It improves hot hardness.	It improves machinability.	Improves wear, corrosion resistance and hardenability.
7. The effect of adding Nickel in steel is	Improves wear, corrosion resistance and hardenability.	It improves toughness.	It improves hot hardness	It improves machinability.	It improves toughness.
8. Ferritic Stainless steels are strengthened by	Hardening.	Tempering.	Cold working.	Normalizing.	Cold working.
9. Ferritic Stainless steels are characterized by	low carbon content.	These contain upto 25% Chromium.	They are magneti	All of these	All of these
10. Martensitic stainless steels contain the	25% and 2 %.	12% and 1.5	18% and 1%.	None of these	18% and 1%.

following percentages of Chromium and Carbon.		%.			
11. Surgical instruments are made from	Ferritic stainless steel.	Martensitic stainless steel.	Austenetic stainless steel.	Duplex stainless steel.	Martensitic stainless steel.
12. Stainless steels which are highly resistant to corrosion are	Martensitic stainless steel.	Ferritic stainless steel.	Austenetic stainless steel.	Duplex stainless steel.	Austenetic stainless steel.
13. Tool steels used for making press tools are called	High speed steels.	Cold work tool steels.	Hot work tool steels.	Shock resisting tool steels.	Cold work tool steels.
14. Tool steels which require good toughness for the manufacture of chisels and punches are called	High speed steels.	Cold work tool steels.	Hot work tool steels.	Shock resisting tool steels.	Shock resisting tool steels.
15. Tool steels used for cutting tools are	High speed steels.	Cold work tool steels.	Hot work tool steels.	Shock resisting tool steels.	High speed steels.
16. Alloy steels with a good strength to weight ratio and greater resistance to corrosion resistance is called	Maraging steels.	HSLA steels.	Special alloy steels	None of these	HSLA steels.
17. Ultrahigh strength steels (2400 MP with good forming capabilities are called	Maraging steels.	HSLA steels.	Special alloy steels	None of these	Maraging steels.
18. Cast irons which are easily machinable are called	White cast iron.	Grey cast iron.	Malleable cast iron.	Nodular cast iron.	Nodular cast iron.
19. Malleabilization treatment is given to	White cast iron.	Grey cast iron.	Malleable cast iron.	Nodular cast iron.	White cast iron.
20. White cast iron is extremely hard and brittle and difficult to machine. This is because	It has higher carbon content.	It has a higher tensile strength.	All the carbon is in the combined form.	None of these	All the carbon is in the combined form.
21. Carbon appears in the free form of carbon flakes in	White cast iron.	Grey cast iron.	Malleable cast iron.	Nodular cast iron.	Grey cast iron

2 marks

1. What are alloy steels? How are alloy steels classified

   Alloy steels mean may steels other than steels. Alloy steels can be divided into two main groups:

   1. Low alloy steels: These contain upto 3 to 4% of alloying elements
   2. High alloy steels: These contain more than 5% of alloying elements

2. Explain stainless steels.

   Stainless steel is alloy of iron, Cr, and other elements that resist corrosion from many environments.

3. What is meant by maraging steel?

   Maraging steels contain 18% nickel, 7% cobalt and small amounts of other elements such as titanium. The carbon content is generally less than 0.05%. To produce a uniform austenite structure, it requires solution treatment at 800- 850^0C followed by a rapid quenching. After solution treatment they are soft enough to be worked and machined with comparative ease.

4. Define tool steel.

   Tool steel are metal used to make tools and ties for cutting forming or otherwise shaping a material into a components or part for a specific applications. Tool steel are metals designed to provide wear resistance and toughness combined with high strength.

5. Name some of the Tool steel.

   1. High Speed steel - Molbdenum grade, Tungsten grade
   2. Cold worked steels (High carbon high chromium grade)
   3. Special purpose steel - Low alloy grade, Carbon tungsten grade

6. Name any two types of aluminium alloys.

   Heat treatable aluminium alloy and non heat treatable aluminium alloy.

7. What are bearing materials?

   The materials which are used for making bearing are known as bearing materials. Ex: White metal, copper base alloy, AL-base alloy, plastic materials and ceramics

8. Define the term copper.

   Copper is a highly ductile metal with high electrical conductivity and the pure metal is used in many electrical and electronic application.

9. Enumerate the important types of copper alloys.

Brasses [CU-ZN alloys], Bronzes [CU-SN alloy, Gun metal [CU-SN- ZN alloy], cupronickels [cu-ni alloy]

10. Describe precipitation hardening.

    It is the most important method of strengthening hardening the most of non ferrous alloys by solid state reaction.

11. What is cast iron?

    Cast-iron can be defined as the ferrous alloy with greater than2% carbon they also contain small amount of silicon manganese and phosphorus.

12. List the properties of steel.

    Ductility, Hardness, Machinability, Shock resistance and Toughness

13. Define metals. Classify engineering metals.

    Metals are elemental substances. Metals are composed of elements which readily give up electrons to provide a metallic bond and electrical conductivity

    Types of metals: 1. Ferrous metals. 2. Non-Ferrous metals.

14. State three reasons why ferrous alloys are used extensively

    Iron based components are relatively abundant and are widely distributed throughout the world. Ferrous materials can be produced very economically. Ferrous materials are versatile. Therefore wide range of mechanical and physical properties of ferrous materials can be achieved

15. State three characteristics of ferrous alloys that limit their utilization

    Heavy in weight, lower electrical and thermal conductivity, lower resistance to corrosion

16. Why is alloying done?

    To increase strength, to improve hardness, to improve toughness, to improve machinability.

17. List four important alloying elements added in alloy steels.

    The most commonly used alloying elements are chromium, nickel, molybdenum, vanadium, tungsten, cobalt, boron, copper and others

18. What are the required good properties of a tool steel?

    Good toughness, Good wear resistance, Very good machinability, Resistance to softening on heating

19. Define 18-4-1 high speed steel.

    Widely used high speed tool steel is 18-4-1 high speed steel. This steel contains 18% tungsten, 4% chromium, 1% vanadium. It is considered to be one of the best of all purpose tool steels.

20. Explain HSLA steels.

    HSLA steels are nothing but high strength low alloy steels. HSLA steels also known as micro alloyed steels, are low carbon steels containing small amounts of alloying elements.

21. What are the effects of carbon on the properties of cast iron?

    If a cast iron contains more of the brittle cementite, then it is mechanical properties will be a poor

22. Write the chemical composition of grey cast iron.

    Carbon-2.5 to 4%, Silicon-1 to 3%, Manganese – 0.4 to 1%, Phosphorus-0.15 to 1%, Sulphur -0.02 to 0.15%, remaining is iron

23. List some bronze alloys.

    Bell bronze, phosphor bronze, aluminum bronze, silicon bronze, coinage bronze, and leaded bronze

24. What are cupronickels? What is the use of monel metal?

    Cupronickels are alloys of copper and nickel. Uses of Monel metal: For making propellers, pump fittings, condenser tubes, steam turbine blades, sea water exposed parts, tanks, and chemical and food handling plants.

25. Define the process "precipitation hardening".

    Precipitation hardening, also known as age hardening, is the most important method of improving the physical properties of some of the non-ferrous alloys by solid state reaction.

26. What is the main strengthening mechanism in high strength aluminum alloys?

    Precipitation strengthening treatment, also known as age hardening is the main strengthening mechanism in high strength aluminum alloys.

27. Explain the effect of chromium and molybdenum in low alloy steels.

    - The effect of chromium in low alloy steels are to: Increase corrosion and oxidation resistance, Increase hardenability and high temperature strength, Resist abrasion and wear.
    - The effect of molybdenum in low alloy steels are to: Improve high temperature creep resistance, Increase hardenability, Stabilize carbides.

28. Mention any two aluminium base alloys and their applications.

    Duralumin: Aircraft and Automobile industries - For making electric cables, in surgical and orthopedic implements etc.

    Y-alloy: Pistons of engines, cylinder heads, gear boxes, propeller blades.

29. What is carbonitriding?

    Carbonitriding is a surface hardening process that involves the diffusion of both nitrogen and carbon into the steel surface.

30. Explain super alloys.

    Super alloys is a general term used to describe the nickel base and cobolt base alloys which have been developed for use at elevated temperatures

31. What are the influences of other elements on carbon steel?

S.No.	ELEMENTS	INFLUENCES
1.	Silicon	It is a powerful graphitizer. Excess results in breakdown of cementite. It increases the harden ability.
2.	Sulphur	It combines with iron and forms ferrous sulphide [FeS] It improves the machinability and lowers the strength.
3.	Phosphorus	It makes the steel brittle and improves the machinablity. It improves the fluidity of casting steels.
4.	Manganese	Increases the machinablity and reduces the brittleness. It increases the yield point strength and toughness of steel by forming stable carbide.
5.	Nitrogen	It increases the strength, hardness and machinablity of the steel and decreases the ductility and toughness.

32. Define chilled cast iron?

It is produced by quick cooling of white cast iron. Chilling is carried out by putting cool steel inserts into the moulds. When the molten metal comes in contact with the chill, it gets cooled quickly and a hard surface is formed. Typical applications are jaw crusher plates, running surface of rail carriage wheels.

33. Explain the effect of following Alloying Materials on steel.

MATERIALS	EFFECTS
Carbon	Increase strength, hardness, wear resistance with increase in carbon and decreases ductility and weldability.
Silicon	Increases hardenability, Removes oxygen in steel, improves resistance to corrosion and oxidation
Phosphorous	Improves machinabilty
Sulphur	Improves machinabilty and Causes brittleness.
Manganese	Improves strength and ductility, machinability, forms hard carbides, deoxidizer.
Chromium	Increase strength, hardness, wear resistance and corrosion resistance, Forms hard and stable carbides.
Tungsten	Forms hard and stable carbides. Improves machinabilty
Molybdenum	Improves creep resistance, strength, toughness, inhibits grain growth and forms hard carbides.

34. Write the constitution of Stainless steel.

18:8 stainless steel [18.0% chromium and 8% nickel]

18:10:3 [18%CHROMIUM, 10% Nickel and 3% molybdenum).

35. Describe HSLA? Where it is used?

High strength low alloy is called as HSLA. This term is used to describe a specific group of steel s that has chemical compositions for desired mechanical properties. They are available in various products, but used as sheet, bar, plate and structural shapes.

36. Explain the important copper alloys and its applications.

ALLOY	COMPOSITION	APPLICATION
Admiralty brass	29% zinc, 1% tin and 70%copper	Bearing material.
Brazing Brass	50% zinc, 50% copper	Brazing purpose
Admiralty Gun metal	88% copper, 5% tin, 5% tin and 2% zinc.	Used for marine work
Leaded Gun metal	85% copper , 5% tin, 55 zinc and 55 lead.	Bearings.

37. Briefly explain cupronickel.

    An alloy of 10% and 30% nickel, 1-2% iron and 2% manganese with copper is called as cupronickel. They have better corrosion resistance and erosion resistance than other alloys in sea water.

38. Write some important bearing alloys and its compositions.

ALLOY COMPOSITION	APPLICATIONS
White metal alloys[babbits]	Electricmotors, Turbines,blowers.
Copper lead alloys20-40% lead.	Connecting rods and main bearings.
Bronze bearing alloys	Bearing in machine tools, home appliances, farm machinery and pumps
Porous metal bearings 90% copper, 10% tin	Machine tools, business machines, farm equipments

39. What is precipitation strengthening?

    In case of some super saturated sold solutions, there is an increase in hardness with time at room temperature after heating to slightly higher temperature. This type of hardening is called precipitation or age hardening.

14 marks

1. What are the main classifications of stainless steel? Explain them.
2. Discuss the different types of stainless steel making reference to approximate composition, structure heat treatment.
3. Give typical application for each of the main categories of stainless steel.
4. Write an engineering brief (composition, heat treatment, properties) about the following steels: [a] Tool steel [b] HSLA steel [c] Maraging steels [d] Spring Steel [e] TRIP steel
5. Explain principle characteristics of cast iron and explain the factors which affect the structure of cast iron.
6. Give the classification of steels. Explain them.
7. Describe the properties and application of low medium and high carbon steels.
8. What is an alloy steels? How are alloy steels classified? Explain them.
9. Discuss the composition properties and typical application of any four copper alloys.
10. Explain the composition properties and typical application of some aluminium alloy?
11. What are the effects of ageing temperature and time on the properties of alloy?

12. Summaries the effect of the flowing elements as alloying additions to steel; [a] manganese [b] silicon [c] chromium [d] vanadium [e] Titanium
13. Discuss any two copper base alloys, giving their properties and applications.
14. Enumerate the composition and properties of malleable and white cast iron.
15. What is precipitation hardening? Illustrate with an example.
16. Enumerate the composition and applications of following alloys (i) Cupronickel (ii) Bronze
    (iii) Bearing Alloy.
17. State the effects of following alloying elements on steel (i) Chromium (ii) Molybdenum.
    Also state any three objectives of adding alloying elements on steel.
18. Using the Al-Cu alloy system as an example, explain the concept of precipitation heat treatment.
19. Explain the purpose of alloying steels with suitable examples from industrial applications.
20. Why copper is a suitable material for automobile radiators? Explain.
21. What are the outstanding properties of cupronickel alloys?

UNIT IV

CERAMICS

Aluminium oxide :

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al2O3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium(III) oxide. It is commonly called alumina, and may also be called aloxide, aloxite, or alundum depending on particular forms or applications. It commonly occurs in its crystalline polymorphic phase α-Al2O3, in which it comprises the mineral corundum, varieties of which form the precious gemstonesruby and sapphire. Al2O3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point.

Properties:

- Hard, wear-resistant
- Excellent dielectric properties from DC to GHz frequencies
- Resists strong acid and alkali attack at elevated temperatures
- Good thermal conductivity
- Excellent size and shape capability
- High strength and stiffness

Applications:

- Wear pads
- Seal rings
- High temperature electrical insulators
- High voltage insulators
- Furnace liner tubes
- Thread and wire guides
- Electronic substrates
- Ballistic armor
- Laboratory instrument tubes and sample holders
- Instrumentation parts for thermal property test machines
- Grinding media

Zirconium oxide ZrO2:

Pure zirconia exists in three crystal phases at different temperatures. At very high temperatures (>2370°C) the material has a cubic structure. At intermediate temperatures (1170 to 2370°C) it has a tetragonal structure. At low temperatures (below 1170°C) the material transforms to the monoclinic structure. The transformation from tetragonal to monoclinic is rapid and is accompanied by a 3 to 5 percent volume increase that causes extensive cracking in the material. This behavior destroys the mechanical properties of fabricated components during cooling and makes pure zirconia useless for any structural or mechanical application. Several oxides which dissolve in the zirconia crystal structure can slow down or eliminate these crystal structure changes. Commonly used effective additives are MgO, CaO, and Y2O3. With sufficient amounts added, the high temperature cubic structure can be maintained to room temperature. Cubic stabilized zirconia is a useful refractory and technical ceramic material because it does not go through destructive phase transitions during heating and cooling. The controlled, stress induced volume expansion of the tetragonal to monoclinic inversion is used to produce very high strength, hard, tough varieties of zirconia available from Accuratus for mechanical and structural applications. There are several different mechanisms that lead to strengthening and toughness in zirconias that contain tetragonal grains. This is a complex subject matter.

Simplistically, these depend on the grain sizes, the thermal history and the kind and amount of stabilizing additive in the body. These variations lead to two strong, commercially available partially stabilized zirconia (PSZ) microstructures identified as TTZ (tetragonally toughened zirconia) and TZP (tetragonal zirconia polycrystal) ceramics. The TTZ is an MgO partially stabilized zirconia often designated MgTTZ or MgPSZ consisting of uniformly dispersed tetragonal precipitates in larger cubic phase crystals. The secondary thermal aging process requiring tight manufacturing controls for proper microstructural development has limited the supplier base for the tetragonally toughened zirconias. The second variety, TZP, is a pure tetragonal phase, very fine grain material stabilized with rare earth oxides, primarily yttria and less commonly ceria. They are often designated YTZP for the yttria stabilized product and CeTZP for the ceria stabilized product. The TZP material has found uses in cutting and wear resistant applications due to its reliable and outstanding hardness and toughness. TZP properties degrade rapidly when the material is exposed to water vapor at 200 to 300°C, so controlled use conditions are important for good performance. All of the toughened zirconias show a degrading of properties with increasing temperature, and this class of high strength, tough materials is generally limited to use temperatures below 800°C

Key Properties of Zirconium Oxide

- Use temperatures up to 2400°C
- High density
- Low thermal conductivity (20% that of alumina)
- Resistance to molten metals
- Wear resistance
- High fracture toughness
- High hardness

.Typical Uses of ZrO2

- Precision ball valve balls and seats
- High density ball and pebble mill grinding media
- Rollers and guides for metal tube forming
- Thread and wire guides
- Hot metal extrusion dies
- Deep well down-hole valves and seats
- Powder compacting dies
- Marine pump seals and shaft guides
- Oxygen sensors
- High temperature induction furnace susceptors
- Fuel cell membranes
- Electric furnace heaters over 2000°C in oxidizing atmospheres

SILICON CARBIDE:

Silicon carbide is composed of tetrahedra of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Silicon carbide is not attacked by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. The high thermal conductivity coupled with low thermal expansion and high strength give this material exceptional thermal shock resistant qualities. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. Chemical purity, resistance to chemical attack at temperature, and strength retention at high temperatures has made this material very popular as wafer tray supports and paddles in semiconductor furnaces. The electrical conduction of the material has lead to its use in resistance heating elements for electric furnaces, and as a key component in thermistors (temperature variable resistors) and in varistors (voltage variable resistors).

Silicon Carbide Properties:

- Low density
- High strength
- Low thermal expansion
- High thermal conductivity
- High hardness
- High elastic modulus
- Excellent thermal shock resistance
- Superior chemical inertness

.

Silicon Carbide Typical Uses:

- Fixed and moving turbine components
- Suction box covers
- Seals, bearings
- Ball valve parts
- Hot gas flow liners

Tungsten carbide:

Tungsten carbide (chemical formula: WC) is a chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes for use in industrial machinery, cutting tools, abrasives, armor-piercing rounds, other tools and instruments, and jewelry.

Tungsten carbide is approximately two times stiffer than steel, with a Young's modulus of approximately 550 GPa, and is much denser than steel or titanium. It is comparable with corundum (α-Al2O3), sapphire and ruby in hardness and can only be polished and finished with abrasives of superior hardness such as cubic boron nitride and diamond, in the form of powder, wheels, and compounds.

Properties:

- Tungsten carbide has a high melting point at 2,870 °C ,a boiling point of 6,000 °C when under a pressure equivalent to 1 standard atmosphere (100 kPa), a thermal conductivity of 84.02 W·m−1·K−1, and a coefficient of thermal expansion of 5.8 µm·m−1·K
- Tungsten carbide is extremely hard, ranking ~9 on Mohs scale and with a Vickers number of 1700–2400. It has a Young's modulus of approximately 550 GPa, a bulk modulus of 439 GPa,[17] and a shear modulus of 270 GPa.It has an ultimate tensile strength of 344.8 MPa. It has a Poisson's ratio of 0.234
- Has low electrical resistivity of (~2×10−7 Ohm·m),
- WC is readily wetted by both molten nickel and cobalt. Investigation of the phase diagram of the W-C-Co system shows that WC and Co form a pseudo binary eutectic. The phase diagram also shows that there are so-called η-carbides with composition (W,Co)6C that can be formed and the fact that these phases are brittle is the reason why control of the carbon content in WC-Co hard metals is important.

Applications:

- Cutting tools for machining
- Surgical instruments
- Jewelry- high resistance to scratching.

Types of thermoplastics.

A thermoplastic, also called a thermosoftening plastic, is a polymer which becomes pliable or moldable above a specific temperature and returns to a solid state upon cooling.

it can be reheated, reshaped, and frozen repeatedly. This quality also makes thermoplastics recyclable.

Above its glass transition temperature Tg, and below its melting point Tm, the physical properties of a thermoplastic change drastically without an associated phase change. Within this temperature range, most thermoplastics are rubbery due to alternating rigid crystalline and elastic amorphous regions, approximating random coils.

Brittleness can be decreased with the addition of plasticizers, which increases the mobility of amorphous chain segments to effectively lower Tg. Modification of the polymer through copolymerization or through the addition of non-reactive side chains to monomers before polymerization can also lower Tg.

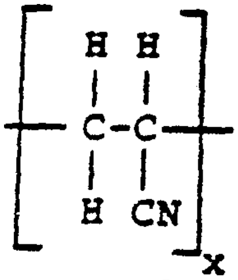
The various types of thermoplastics are given below

1. **Acrylonitrile Butadiene styrene**
2. **Polymethyl metacrylate**
3. **Polyamides**
4. **Polyvinyl chloride**

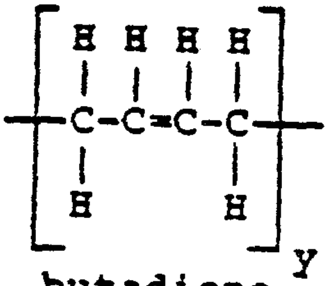
1. Acrylonitrile Butadiene styrene:

ABS is a common thermoplastic. ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of polybutadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The styrene gives the plastic a shiny, impervious surface. The polybutadiene, a rubbery substance, provides resilience even at low temperatures its glass transition temperature is approximately 105 °C is amorphous and therefore has no true melting point.

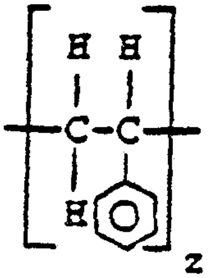
ABS polymers are resistant to aqueous acids, alkalis, concentrated hydrochloric and phosphoric acids, alcohols and animal, vegetable and mineral oils, but they are swollen by glacial acetic acid, carbon tetrachloride and aromatic hydrocarbons and are attacked by concentrated sulfuric and nitric acids. They are soluble in esters, ketones, ethylene dichloride and acetone



acrylonitrile



butadiene

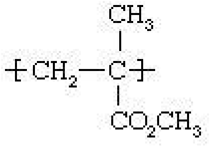


styrene

Polymethyl methacrylate (PMMA):

It is a synthetic resin produced from the polymerization of methyl methacrylate. A transparent and rigid plastic, PMMA is often used as a substitute forglass in products such as shatterproof windows, skylights, illuminated signs, and aircraft canopies. It is sold under the trademarks Plexiglas, Lucite, and Perspex.

PMMA, an ester of methacrylic acid ($CH_2=C[CH_3]CO_2H$), belongs to the important acrylicfamily of resins. In modern production it is obtained principally from propylene, a compound refined from the lighter fractions of crude oil. Propylene and benzene are reacted together to form cumene, or isopropylbenzene; the cumene is oxidized to cumene hydroperoxide, which is treated with acid to form acetone; the acetone is in turn converted in a three-step process to methyl methacrylate ($CH_2=C[CH_3]CO_2CH_3$), a flammable liquid. Methyl methacrylate, in bulk liquid form or suspended as fine droplets in water, is polymerized (its molecules linked together in large numbers) under the influence of free-radical initiators to form solid PMMA. The structure of the polymer repeating unit is



$$\left[CH_2 - \overset{\displaystyle CH_3}{\underset{\displaystyle CO_2CH_3}{C}} \right]$$

Structures, properties and applications of the Phenol formaldehyde and Urea formaldehyde.

Phenol formaldehyde structure:

Phenol formaldehyde (PF) are synthetic polymers obtained by the reaction of phenol or substituted phenol with formaldehyde. Phenolic resins are mainly used in the production of circui boards. They are better known however for the production of molded products including pool balls, laboratory countertops, and as coatings and adhesives. In the form of Bakelite, they are the earliest commercial synthetic resin.

Phenol-formaldehyde resins, as a group, are formed by a step-growth polymerization reaction that can be either acid- or base-catalysed. Since formaldehyde exists predominantly in solution as a dynamic equilibrium of methylene glycol oligomers, the concentration of the *reactive* form of formaldehyde depends on temperature and pH.

Phenol reacts with formaldehyde at the ortho and para sites (sites 2, 4 and 6) allowing up to 3 units of formaldehyde to attach to the ring. The structure is shown below

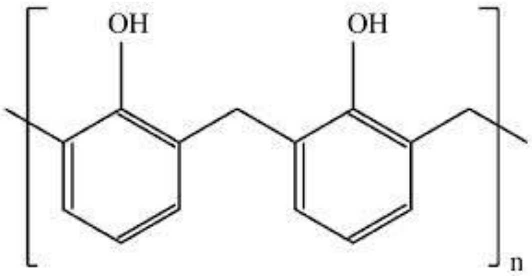


Figure: Structure of Phenol-formaldehyde

Properties:

1. **Easily moldable**
2. **High electrical insulation**
3. **High rigidity and strength**
4. **High hardness**

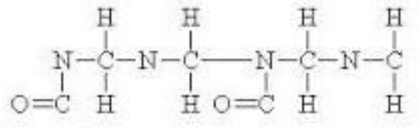
Applications:

5. **Phenolic resins are also used for making exterior plywood commonly known as WBP (Weather & boil proof)**
6. **Phenolic resin is used as a binder in loudspeaker driver suspension components which are made of cloth.**
7. **Bakelite is made from phenolic resin and wood flour**
8. **Novotext is cotton fibre-reinforced phenolic, using randomly oriented fibres.**

Urea-formaldehyde structure:

Urea-formaldehyde, also known as urea-methanal, so named for its common synthesis pathway and overall structure. It is a non-transparent thermosetting resin or plastic, made from urea and formaldehydeheated in the presence of a mild base such as ammonia or pyridine. These resins are used in adhesives, finishes, MDF, and molded objects.

The chemical structure of UF resins can be described as that of an aldehyde condensation polymer. This description leaves the details of the structure undetermined, which can vary linearly and branched. These are grouped by their average molar mass and the content of different functional groups. Changing synthesis conditions of the resins give good designing possibilities for the structure and resin properties.The below structure shows the structure of Urea-formaldehyde



Urea Formaldehyde

Properties:

- Urea-formaldehyde resin's attributes include high tensile strength
- High flexural modulus and heat distortion temperature
- High surface hardness
- Low water absorption
- Low mould shrinkage, elongation at break, and volume resistance

Applications:

- Urea formaldehyde was commonly used when producing electrical appliances casing (e.g. desk lamps).
- For decorative laminates
- As foundry sand molds
- For textiles, paper and wrinkle resistant fabrics
- As cotton blends, rayon and corduroy
- As insulation foam

Engineering ceramics:

Engineering ceramics are structured and functional ceramics used in applications differing from those employing classical utility ceramics such as brick, clinker, ovenware, porcelain, sanitary ceramics or tiles. However, the differentiation is not only made in terms of applications, but also material. Clay and silicate ceramics are therefore considered utility ceramics, while all others are oxidic, non-oxidic and mixed ceramics such as aluminium oxide, zirconium oxide, silicon carbide or lead zirconate titanate, just to mention a few, and designated engineering or technical ceramics.

Ceramic materials whose characteristics have been specifically optimised to suit the majority of industrial applications are used in compliance with the requirements catalogue. They can resist temperatures of up to 2500°C in furnace construction and burner systems. Ceramic bearing casings in gas turbines operate with minimal wear at speeds of several thousand revolutions per minute and temperatures of about 1500 °C. Pumps with ceramic friction bearings utilised in sea water desalination plants convey sea water heavily contaminated with sand for years without exhibiting any noticeable erosion or corrosion. Use of ceramic components in spark plugs and as condensers or insulators still belongs to the most important applications in terms of numbers. The variation spectrum of these materials is best demonstrated in this area. While some electrically insulate, others (supraconductors) conduct electrical current with absolutely no resistance.

The range of processes for producing components from engineering ceramics is as broad as the materials spectrum. However, almost all share important procedure characteristics. A green compact is made of a raw mass (sludge, feedstock) or powder at a comparatively low temperature which only obtains its material characteristics in a sintering process at high temperatures. The material properties of ceramic products are therefore inseparable associated with the characteristics of raw materials and the production process, consisting of preparation, shaping and sintering. The engineering skill lies herein – in precision influencing of microstructures through shaping and in the sintering process.

1. Silicon carbide :

Silicon carbide (SiC) is certainly the most important non-oxidic ceramic material. It generally excels on account of its high hardness and good wear resistance, high strength even at high temperatures and good thermal spalling resistance combined with low thermal expansion, but high thermal conductivity. However, the high covalent bond, which is responsible for this, also impedes the production of SiC as its tendency towards sintering is distinctly lower in comparison with oxide ceramics. This means that a great number of different techniques is used for manufacturing SiC ceramic products, differing not only in method control but also with regard to the properties of the SiC produced. The forming operation may utilize all ceramic methods known; slip and die casting, axial and isostatic pressing, injection moulding, extrusion moulding, film casting and other methods are used. Differences arise in the final compaction, which may be achieved in greatly varying ways

2. Aluminium oxide:

Aluminium oxide occurs as a natural raw material in its thermodynamically stable phase (corundum or alpha-Al_2O_3) and also in monocrystalline form as sapphires or rubies created by the embedding of different metallic salts. In addition to naturally-occurring or artificially-produced alpha-Al_2O_3 (sintered corundum), gamma-Al_2O_3(alumina) and beta-Al_2O_3 (as an ionic conductor) are also used in engineering ceramic applications.

Aluminium oxide is one of the most important oxide ceramic materials and finds use in probably the broadest number of engineering applications. Aluminium oxide ceramics are distinguished by their extreme hardness, strength and temperature stability and exhibit a high degree of resistance to wear and corrosion, even at high temperatures. They are also excellent electrical insulators, while simultaneously acting as adequate thermal conductors (in a densely sintered condition). However, they demonstrate poor resistance to fracturing, making Al_2O_3 components sensitive to impact and edge loading.

3. Magnesium Oxide:

A noteworthy characteristic of this material is excellent electrical insulation and simultaneously high thermal conductivity (in densely sintered condition) and high temperature resistance up to approx. 2700 °C. Components made of MgO are for this reason preferred for refractory ceramics, as furnace lining, for laboratory appliances or as filler when shaping metal pipes in the production of tubular radiators, immersion heaters und heating elements.

4. Zirconium oxide:

Zirconium oxide is, next to aluminium oxide, the most widely used oxide ceramic for structural and, in particular, functional applications. The most important technical modifications of ZrO_2 are polycrystallines, tetragonal zirconium oxide (TZP) and partially stabilised zirconium oxide (PSZ). Cubic fully-stabilised ZrO_2 (FSZ or CSZ) plays a less important role, due to its unfavourable mechanical properties. Diffusants are added to zirconium oxide to stabilise these thermodynamic phases (which are unstable below 1170°C). These are mainly magnesium oxide, calcium oxide, yttrium oxide or ceroxide and are added in differing quantities. This avoids conversion to the stable monoclinic phase encountered at low temperatures and, consequently, the volumetric leap associated with this process which would otherwise lead to destruction during production or use.

The addition of stabilizers creates oxygenic defects in the zirconium oxide structure which considerably favor the conveying of ions. This leads to a high level of oxygen ion conductivity at higher temperatures. Zirconium oxide is also distinguished by a high resistance to breakage when compared to other ceramics and glasses, along with excellent strength, a high degree of resistance to wear and corrosion and low thermal conductivity.

MCQ

Questions	opt1	opt2	opt3	opt4	answer
The elastic stress strain behaviour of rubber is	linear	non-linear	plastic	no fixed relationship	non-linear
Thermosetting plastics	soften on the application of heat and can be repeatedly molded	will not deform when again subjected to heat	are produced on a synthetic resin base	are synthetic base resins having a predefined setting temperature	are produced on a synthetic resin base
Other than elasticity and rubber like material, the important property of polyvinyl chloride (PVis	odourless	colourability	non-flammable	impervious to water	non-flammable
Filler is used in plastics to	completely fill up the voids created during manufacturing	improve plasticity, strength and toughness	to provide colour, strength, impact and resistance and reduce cost	to accelerate the condensation and polymerization	to provide colour, strength, impact and resistance and reduce cost
Which of the following moulding methods is generally not used for thermoplastic materials	extrusion	injection	casting	calendaring	casting
One of the main disadvantage of thermosetting and thermo-plastic plastic is that	they deform under heat and pressure	they are resistant to water upto 100 degree celcius only	they do not possess high mechanical strength	their shape cannot be changed without application of heat.	they do not possess high mechanical strength
Polyesters belong to the group of	thermoplastic plastics	thermosetting plastics	elastomers	None of these	thermosetting plastics

Which one of the following is a ceramic material?	Zinc	iron	silicon carbide	None of these	silicon carbide
Which of the followings are the mechanical properties of materials?	fatigue	specific heat	creep	All of these	All of these
The oxides, nitrides, carbides and silicates of metals are known as	organic materials	ceramic materials	ferrous materials	non-ferrous materials	ceramic materials
The polymeric materials composed of carbon compounds are known as	organic materials	ceramic materials	ferrous materials	non-ferrous materials	organic materials
White metal is best suited as a bearing material for	lighter duty bearings	heavier duty bearings	medium duty bearings	None of these	heavier duty bearings
Certain ceramic materials are used for tape-recorder heads because they have	low tensile strength	high compressive strength	great hardness and resistance to wear	low fracture strength	great hardness and resistance to wear
Silicon carbide is a	natural abrasive	synthetic abrasive	artificial abrasive	None of these.	synthetic abrasive
Which of the followings are examples of polymers?	starch	nylon	wood	All of these	All of these
The resistance of a metal to plastic deformation by indentation is known as	stiffness	toughness	hardness	creep	hardness
The dominant property of cellulosics, a form of thermoplastics is	ease of working and toughness	corrosion resistance and mechanical strength	good heat and wear resistance and fine grain structure	god colour, finish, texture and light transmissibility	ease of working and toughness
The degradation of plastics is accelerated by	high ambients	dampness	corrosive atmosphere	ultraviolet radiation	ultraviolet radiation
Examples of Traditional Ceramics are	Clay Products	Glasses	Cement	All of these	All of these
ABS stands for	Acrylonitrile Benze Styrene	Acetelene Benzene Styrene	acrynonitryl butadiene styrene	None of these	acrynonitryl butadiene styrene

2 marks

1. Define the term polymer?

   The term polymer is derived from the two greek words poly[means many] meros[means unit] thus polymers are composed of a large number of repeting units [small molecules] called monomers

2. What are synthetic polymers?

   Polyethylene, polystyrene, nylon, terylene, dacron, etc are synthetic polymers and are termed under plastic, fibres and elastomers.

3. Explain condensation polymerization.

   Condensation polymerization is the formation of polymers by stepwise intermolecular chemical reactions that normally involve more than one monomer speices.

4. How are polymers classified?

   Polymers are classified according to the mechanical behavior at elevated temperatures as

   1. Thermoplastics (or thermoplastic polymers) 2.Thermosets (or thermosetting polymers)

   3.

   Elastomers.

5. Explain the application of types of thermoplastics.

   1. Polyvinyl chloride (PVC) and polystyrene used in articles such as plastic wall and floor tile.
   2. Polystyrene-Flouresent light reflectors.
   3. Polymethyl Methacrylate –Plastic lenses.

6. What is the characteristic of thermoplastics?

   Thermoplastics (or) Thermoplastic polymers soften when heated (and eventually liquify) and harden when cooled. They can be repeatedly moulded and remoulded to the desired shapes.

7. Define plastics.

   A plastic is defined as an organic polymer, which can be moulded into any desired shape and size with the help of heat, pressure (or)both. The plastic, in its liquid form, is known as resin.

8. What are the thermosetting polymers?

   1. Epoxies.2.Phenolics.3.Polyesters.4Urea formaldehyde.5.Melamine formaldehyde.

9. Define rubber.

   The rubber may be defined as an organic polymer ,which elongates on stretching and regains its original shape after the removal of the stress.

10. Explain ceramics.

    Ceramic material are defined as those containing phase that are compounds of metallic and non-metallic elements .In short ,ceramics are inorganic, non-metallic materials.

    Ex: Stone, brick, concrete, clay, glass, vitreous enamel and refractories. Majority of these are composed of silicates.

11. Name two refractory materials.

    The ceramics materials such as magnesia (with melting point of 2880 ^{0}C) and alumnia (with melting point of 2040^{0}C) are excellent choice of refractory materials.

12. What are applications of poly styrene's?

    1. Packaging 2. Insulation foams. 3. Lighting panels. 4. Egg boxes. 5. Walls Tiles. 6. Battery cases.

13. Define Slip and Twinning types of deformation.

    Slip deformation is defined as the sliding of blocks of crawl over one another along definite crystallographic planes called slip planes, Whereas Twinning deformation is atoms in a part of crystal subjected to stress, and rearranging themselves so that one part of crystal becomes a mirror image of another part.

14. List any four attractive characteristics of polymers.

    Low density, Good thermal and electrical insulation properties, High resistance to chemical attack, Ease of fabrication, relatively low cost

15. What is meant by isomerism?

    Isomerism is a phenomenon wherein different atomic configurations are possible for the same configuration

16. Differentiate commodity plastics with engineering plastics.

    The plastics which are not generally used for engineering applications are known as commodity plastics. The plastics which are used in engineering applications are known as engineering plastics.

17. Name any four commodity plastics and engineering plastics.

    Commodity plastics: Polyethylene, Polypropylene, Polystyrene, Polyvinyl chloride
    Engineering plastics: Ethenic, Polyamides, Cellulosics, Acetals

18. What are the sources of raw materials for plastics?

    Animal and vegetable by products, Coal by products, Petroleum by products

19. Write short notes on nylons.

    Nylons also known as Polyamides are the product of condensation reaction between an amine and an organic acid

20. Describe engineering ceramics.

    Engineering ceramics are also known as technical/industrial ceramics, are those ceramics that are specially used for engineering applications or in industries

21. Name any four engineering ceramics.

    Alumina, Silicon carbide, Silicon nitride, Sialons

22. What are composites?

    Composites are produced when two are more materials are joined to give a combination of properties that cannot be attained in the original materials.

23. Explain the role of matrix material in a composite.

    The matrix usually provides the major control over electrical properties, the chemical behavior, and elevated temperature use of the composite.

24. Write the general mechanical properties of ceramics.

    Ceramics are strong, hard and brittle, they are good thermal and electrical insulators, they have high compressive strength but are weak in tension.

25. What do you meant by copolymers?

    Copolymers are polymers which are obtained by adding different types of monomers

26. How are refractories classified?

    Fire clay refractories, Silica refractories, Basic refractories, Special refractories

27. Give two examples of particulate reinforced metal matrix composites.

    Sintered Aluminium Powder (Al/Al2O3),
    Cermet,

28. Explain Cermets and its applications.

    Ceramic metal composite containing between 80 to 90% of ceramics are known as Cermets. Applications: Cutting tools, Slip gauge, wire drawing dies, rocket motor and jet engine parts.

29. What are the constituents of composites?

    Composites are composed of two phases: Matrix phase, Dispersed phase

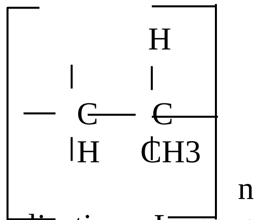
30. Name any four engineering polymers.

    Ethenic, Polyamids, Silicones, Polyimides.

31. What is polymer?

    Polymer interchangeably called as plastic materials made by polymerization with repeated molecules that contains as an essential ingredient an organic substance of large molecular weight, is solid in its finished state.

32. Draw the structure of Polypropylene [PP] and write the applications H



$$\left[-\underset{H}{C}-\overset{H}{\underset{CH_3}{C}}-\right]_n$$

    Applications: Luggage, Battery cases, Tool Boxes, Filaments

33. Write the properties of Polystyrene and its applications.

    Excellent moldability, Poor impact strength, Melting Point 115 ^{0}C, It can be made into rigid foam. Applications: Plastic tableware, Food containers and toys

34. Describe Torlon.

    Polyamide-imide is called as Torlon. It consists of amide and imide group linkages with nitrogen bond. They are used in higher temperature load applications, high temperature wire varnishes, glass, fibers.

35. What is carbon- carbon composite?

    In the carbon – carbon composite the matrix is carbon-graphite and the reinforcement is carbon fibers. These composites are used for light weight coupled with high temperature applications

36. Name some industrial items made from carbon-graphite.

    Nose piece and leading edges of the wings on the space shuttle, less exotic applications, brake linings for large aircraft.

37. Explain vitrification. When is it used?

    Vitrification is a densification process in ceramic manufacturing. This done by heating the formed component to higher temperature below its melting point. At this temperature atoms diffuses and forms a hard structure.

38. What is the effect of porosity in ceramics? How can porosity be reduced?

    Porosity reduces the strength of the ceramics. Porosity can be reduced by using proper binders, Vitrified at higher Temperatures, fine grain ceramic particles.

14 marks

1. Describe the difference between thermoplastics and thermosetting plastics.
2. Write on engineering brief about the flowing thermoplastics;
   [a] polyethylene[b] Polyvinyl chloride [c] Acetyl [d] polyamides
3. List the properties and typical application of the following thermoplastics [a] PTFE [b] PMMA[c] PET [d] PEEK [e] PE
4. What are ceramics? List and briefly explain five important properties of ceramics that make them useful engineering materials. Explain the main classification of ceramic materials.
5. Discuss the properties and typical application of the following engineering ceramics?
   [a] Al2O3 [b] SIC [c] SI3N4 [d] PSN [e] Silons
6. List the advantages and limitations and application of composite materials.
7. Explain the difference between commodity plastics and engineering plastics.
8. Describe the molecular structures properties and application of the following polymers.

[a] polyvinyl chloride[PVC] [b] polystyrene[PS] [C] Polyethylene terephthalate[PET] [d] polycarbonate[PC]

9. Give a detailed account on:
   [a] urea formaldehyde [b] fibre rain forced plastics [c] cellulose nitrate
10. Explain the following terms with respect to polymers (1) Mechanical behavior (2) Thermal behaviour (3) Electrical behaviour.
11. What are the special properties of plastics that make them suitable for engineering applications? Describe the concept of ‘Co-polymerization’.
12. List the important engineering ceramics and its applications. Discuss the properties and applications of Si3N4 and SiC.
13. Discuss the structure and applications of any four thermoplastic and any four thermoset plastic materials.
14. Discuss the properties and applications of the following four ceramics.
    (1) Silica (2) Zirconia (3) SiC (4) Cubic boron nitride.
15. What are the fibre reinforced plastics? Name any four fibres and their matrix material.
16. Write short notes on: (i) Ceramics (ii) Urea Formaldehyde (iii) Phenol Formaldehyde.
17. Explain the properties and applications of the following poymers and discuss anyone fabrication methods of polymers. (I) PMMA (II) PP (III) ABS and (IV) Glass.
18. List the important engineering ceramic materials and discuss its general applications of ceramic materials in various engineering fields. What are the advantages and disadvantages of ceramics?
19. Describe the terms: (1) Linear Polymer (2) Branched Polymer (3) Chain Stiffening (4) Cross linked Polymer.
20. Describe cemented carbide and how they are made? Explain the step by step process.
21. What is polymerization? Describe addition polymerization and condensation polymerization.
22. How plastic materials are classified? Explain each classification.

UNIT V

VICKERS HARDNESS TEST:

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 120 kg. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kg load by the square mm area of indentations.

$$HV = \frac{2F\sin\frac{136^o}{2}}{d^2} \qquad HV = 1.854\,\frac{F}{d^2}$$

F= Load in kg
d = Arithmetic mean of the two diagonals, d1 and d2 in mm HV = Vickers
hardness

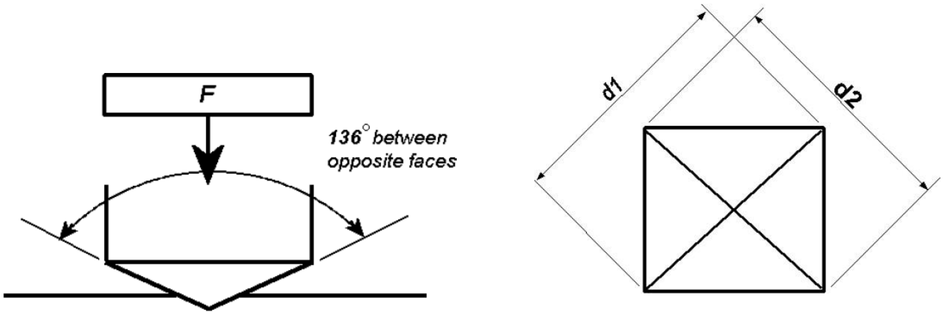


Figure. Indenter

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula, but is more convenient to use conversion tables. The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10 kgf force. Several different loading settings give practically identical hardness numbers on uniform material, which is much better than the arbitrary changing of scale with the other hardness testing methods. The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the softest and hardest of materials, under varying loads

Advantages:

- Provide a fairly wide acceptance for research work because it provides a continuous scale of hardness, for a given load.
- Micro Vickers hardness test is also used for small or thin parts, part thickness can be thin to 3mm.
- VHN = 5-1,500 can be obtained at the same load level so easy for comparison.

Limitations:

- The Vickers machine is a floor standing unit that is more expensive than the Brinell or Rockwell machines.
- The barrel-shaped indentation is found in cold-worked metals, resulting from ridging or piling up of the metal around the faces of the indenter, producing a low value of contact area giving too high hardness value.

Rockwell hardness test

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load $F0$ (Fig. 1A) usually 10 kgf. When equilibrium has been reached, an indicating device

Which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig. 1B). When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig. 1C). The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

HR = $E - e$
$F0$ = preliminary minor load in kgf
$F1$ = additional major load in kgf
F = total load in kgf
e = permanent increase in depth of penetration due to major load F1 measured in units of 0.002 mm
E = a constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter
HR = Rockwell hardness number
D = diameter of steel ball

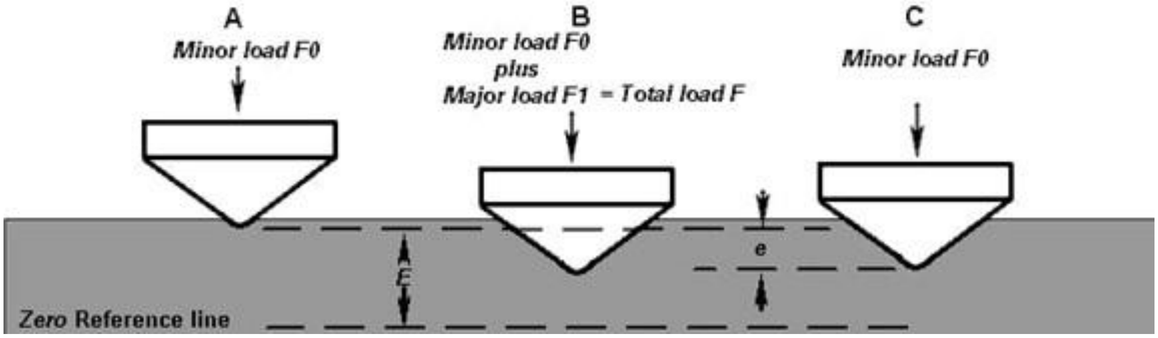


Figure Indentions

ROCKWELL HARDNESS SCALES

Scale	Indenter	Minor Load $F0$ kgf	Major Load $F1$ kgf	Total Load F kgf	Value of E
A	Diamond cone	10	50	60	100
B	1/16" steel ball	10	90	100	130
C	Diamond cone	10	140	150	100
D	Diamond cone	10	90	100	100

Typical application of rockwell hardness scales

HRA . . . . Cemented carbides, thin steel and shallow case hardened steel HRB . . . . Copper alloys, soft steels, aluminium alloys, malleable irons, etc. HRC .... Steel, hard cast irons, case hardened steel and other materials harder than 100 HRB

HRD .... Thin steel and medium case hardened steel and pearlitic malleable iron

LIQUID PENETRANT TESTING

The liquid penetrant testing requires the following five steps:

1. Pre-cleaning

The test surface is cleaned to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Cleaning methods may include solvents, alkaline cleaning steps, vapor degreasing, or media blasting. The end goal of this step is a clean surface where any defects present are open to the surface, dry, and free of contamination. Note that if media blasting is used, it may "work over" small discontinuities in the part, and an etching bath is recommended as a post-blasting treatment.

2. Application of Penetrant:

The penetrant is then applied to the surface of the item being tested. The penetrant is allowed "dwell time" to soak into any flaws (generally 5 to 30 minutes). The dwell time mainly depends upon the penetrant being used, material being tested and the size of flaws sought. As expected, smaller flaws require a longer penetration time. Due to their incompatible nature one must be careful not to apply solvent-based penetrant to a surface which is to be inspected with a water-washable penetrant.

3. Excess Penetrant Removal:

The excess penetrant is then removed from the surface. The removal method is controlled by the type of penetrant used. Water-washable, solvent-removable, lipophilic post-emulsifiable, or hydrophilic post-emulsifiable are the common choices. Emulsifiers represent the highest sensitivity level, and chemically interact with the oily penetrant to make it removable with a water spray. When using solvent remover and lint-free cloth it is important to not spray the solvent on the test surface directly, because this can remove the penetrant from the flaws. If excess penetrant is not properly removed, once the developer is applied, it may leave a background in the developed area that can mask indications or defects. In addition, this may also produce false indications severely hindering your ability to do a proper inspection

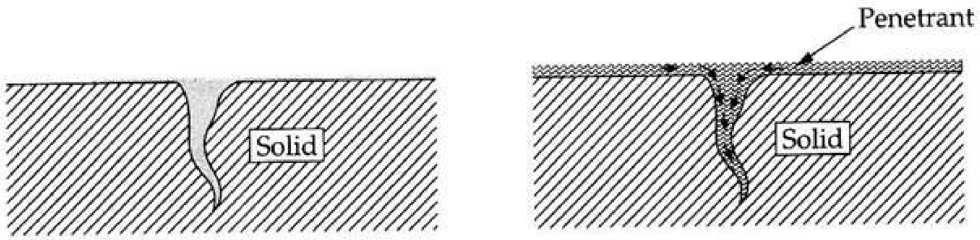
4. Application of Developer:

After excess penetrant has been removed a white developer is applied to the sample. Several developer types are available, including: non-aqueous wet developer, dry powder, water suspendable, and water soluble. Choice of developer is governed by penetrant compatibility (one can't use water-soluble or suspendable developer with water-washable penetrant), and by inspection conditions. When using non-aqueous wet developer (NAWD) or dry powder, the sample must be dried prior to application, while soluble and suspendable developers are applied with the part still wet from the previous step. NAWD is commercially available in aerosol spray cans, and may employ acetone, isopropyl alcohol, or a propellant that is a combination of the two. Developer should form a semi-transparent, even coating on the surface.

The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out. Any areas that bleed-out can indicate the location, orientation and possible types of defects on the surface. Interpreting the results and characterizing defects from the indications found may require some training and/or experience [the indication size is not the actual size of the defect

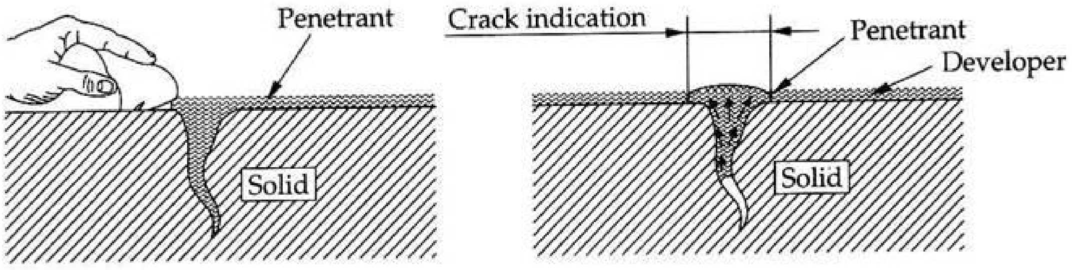
5. Inspection:

The inspector will use visible light with adequate intensity for visible dye penetrant. Ultraviolet (UV-A) radiation of adequate intensity (1,000 micro-watts per centimeter squared is common), along with low ambient light levels for fluorescent penetrant examinations. Inspection of the test surface should take place after 10 to 30 minute development time, depends of product kind. This time delay allows the blotting action to occur. The inspector may observe the sample for indication formation when using visible dye. It is also good practice to observe indications as they form because the characteristics of the bleed out are a significant part of interpretation characterization of flaws. The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.



(a) Cleaning and drying of test surface

(b) Application of penetrant to test surface



(c) Removal of penetrant from test surface

(d) Application of developer

Penetrants are carefully formulated to produce the level of sensitivity desired by the inspector. The penetrant must possess a number of important characteristics as follows:

a. Spread easily over the surface of the material being inspected to provide complete and even coverage.
b. Be drawn into surface breaking defects by capillary action.
c. Remain in the defect but remove easily from the surface of the part.
d. Remain fluid so it can be drawn back to the surface of the part through the drying and developing steps.
e. Be highly visible or fluoresce brightly to produce easy to see indications.
f. Not be harmful to the material being tested or to the inspector.
g. Must possess good removability after test was over.

Radiographic testing

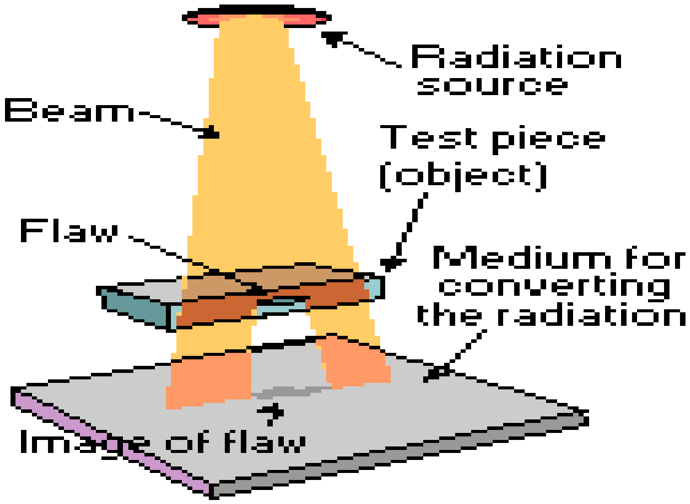


Fig 1. Radiographic testing

It is a non-destructive testing of components and assemblies that is based on differential absorption of penetrating radiation- either electromagnetic radiation of very short wave-lengths or particulate radiation by the part or test piece being tested. Because of differences in density and variations in thickness of the part, or differences in absorption characteristics caused by variation in composition, different portions of a test piece absorb different amounts of penetrating radiation. Unabsorbed radiation passing through the part can be recorded on film or photosensitive paper, viewed on a florescent screen or monitored by various types of electronic radiation detectors.

The term radiography testing usually implies a radiographic process that produces a permanent image on film or paper. Although in a broad sense it refers to all forms of radiographic testing. Neutron radiography refers to radiographic testing using a stream of neutrons rather than electromagnetic radiation.

Uses

Industrial Radiography inspection is used to detect features of a component or assembly that exhibit a difference in thickness or physical density as compared to surrounding material. Large differences are more easily detected than small ones. In general, radiography can detect only those features that have an appreciable thickness in direction parallel to the radiation beam. This means that the ability of the process to detect planar discontinuities such as cracks depends on proper orientation of the test piece during testing. Discontinuities such as voids and inclusions, which have measurable thickness in all directions, can be detected as long as they are not too small in relation to section thickness. In general, features that exhibit a 2% or more difference in absorption compared to the surrounding material can be detected. Radiography is more effective when the flaws are not planar.

Applicability

Radiographic testing is used extensively on castings and weldments. Radiography is well suited to the testing of semiconductor devices for cracks, broken wires, unsoldered connections, foreign material and misplaced components. Sensitivity of radiography to various types of flaws depends on many factors, including type of material, type of flaw and product form. Both ferrous alloys can be radio graphed, as can non-metallic materials and composites.

Limitations

Compared to other NDT methods, radiography is expensive. Relatively large capital costs and apace allocations are required for a radiographic laboratory. Field testing of thick sections is a time consuming process. High activity sources require heavy shielding for protection of personnel. Tight cracks in thick sections usually cannot be detected at all, even when properly oriented. Minute discontinuities such as inclusions in wrought material, flakes, micro- porosity and micro-fissures cannot be detected unless they are sufficiently segregated to yield a detectable gross effect. Laminations are impossible to detect with radiography, because of their unfavorable orientation. Laminations do not yield differences in absorption that enable laminated areas to be distinguished from limitation free areas.

It is well known that large doses of X-rays or gamma rays can damage skin and blood cells, can produce blindness and sterility, and in massive doses can cause severe disability or death. Protection of personnel not only those engaged in radiographic work but also those in the vicinity or radiographic testing is of major importance. Safety requirements impose both economic and operational constraints on the use of radiography for testing.

MCQ

Questions	**opt1**	**opt2**	**opt3**	**opt4**	**answer**
The tendency of the brittle fracture is increased with	decreasing temperature	increasing temperature	increasing and decreasing temperature.	All of these	decreasing temperature
Griffith theory is valid only to	ductile material	brittle material	both (a) and (b)	None of these	brittle material
__________fracture is called cup- and -cone fracture	ductile fracture	brittle fracture	fatigue fracture	creep fracture	ductile fracture
___________materials are often used for compression tests	ductile material	brittle material	both (a) and (b)	None of these	brittle material
The total energy absorbed by the materials before fracturing is called	stiffness	ductility	toughness	malleability	toughness
The property of a material by virtue of which it resists deformation is called	creep	toughness	hardness	stiffness	stiffness
The property of material by virtue of which it can withstand varying stresses is	impact strength	resilience	endurance	None of these	endurance
The plastic deformation in crystalline materials occurs at temperature lower than	0.4 tm	Above 0.4 Tm	Below 0.4 Tm	All of these	0.4 tm
The tendency of the brittle fracture increases with	increasing strain rate	decreasing strain rate	no change in strain rate	both increasing and decreasing strain rate	increasing strain rate
Hardness is the property of material by virtue of which it is able to resists	force and intendation	abrasion and intendation	force and abrasion	fracture	abrasion and intendation
Materials having fine grain structure will have	high yield strength, high tensile strength and high	high yield strength, low tensile strength and low	high hardness	None of these	igh yield strength, high tensile strength and high hardness

	hardness	hardness			
The slip occurs by	rotational motion of sliding planes	sliding of the specimen	translatory motion along sliding planes and rotation of the specimen	All of these	translatory motion along sliding planes and rotation of the specimen
Twinning occurs due to	sliding of planes	presence of dislocations	material defects	growth and movement of dislocations in the crystal lattice	growth and movement of dislocations in the crystal lattice
Fracture is caused due to	excessive loads	cracks	material deformation	action of stresses	cracks
In crystalline material the fracture takes place normal to the specific crystallographic planes is called	slipping plane	twinning plane	cleavage plane	fracture plane	cleavage plane
Ductile fracture occurs by	compressive loads	presence of cracks	slow tearing of metals	All of these	slow tearing of metals
Fatigue fracture occurs at stresses	below the tensile stress of the material	above the tensile stress of the material	at the tensile stress of the material	at the shear load	below the tensile stress of the material
Secondary creep is usually termed as	instaneous elongation	steady state creep	recovery effect	None of these	steady state creep
Which of these belongs to non- destructive testing	tensile test	impact test	fatigue test	ultrasonic test	ultrasonic test
Which of these belongs to destructive testing	ultrasonic test	liquid penetration test	magnetic particle test	tensile test	tensile test

2 marks

1. Explain twinning.

   Twinning is the two plastic deformation which takes place along the planes due to a set of forces acting on a given metal. The two planes are usually parallel to each other and are called the twin planes. Here each atom moves only a fraction of an inter – atomic distance relative to its neighbours.

2. Define fracture.

   Fracture can be defined as the breaking up (or) separation of a solid into two (or) more parts when subjected to an external load.Fracture can occur as the end result of extensive plastic deformation (or)as the end result of fatigue in a part of the material.

3. What is brittle fracture?

   A brittle fracture can be defined as a fracture which is the result of intense localized plastic deformation and very rapid crack propagation. It consists of destroying the interatomic bonds with normal stresses.

4. Define ductile fracture.

   A ductile fracture can be defined as a fracture which is the result of intense localised plastic deformation of the metal at the tip of the crack .At elevated temperatures all fractures tend to become ductile because slip can occur more easily.

5. Explain the fatigue fracture.

   Fatigue fracture is the fracture that occur under repeatedly applied fatigue stresses. This fractures occurs at a stress well below the tensile strength of the materials.

6. Define creep fracture.

   Creep fractures is seen to take place by two ways: Sliding of grain boundaries, Movement of dislocations from one slip to another by climbing.

7. What is the use of tensile test?

   The tensile test is used to determine the mechanical properties of material. It also gives information on how material behave under tensile loading condition.

8. Define elastic limit.

   The elastic limit can be defined as the greatest amount of stress that the material can withstand and still return to its original state when the load is removed .

9. What is proportional limit?

   Proportional limit is the stress at which stress-strain curve deviates from linearity.

10. Explain the use of Izod test.

    The Izod test is the impact test which is used to determine the impact strength of a material.

11. Define endurance limit in fatigue test.

    Endurance limit is defined as the value of stress below which the material will not fail when it is loaded for infinite number of cycles.

12. What properties are determined from tension testing of metallic products?

    (1) Limit of proportionality ,(2)Yield strength, (3) Maximum tensile

strength,

(4) Breaking strength, (5) Percentage elongation, and (6) Modulus of elasticity.

13. Differentiate between Fatigue and Creep tests.

    Fatigue test s are to test the metal load carrying capacity of repeated load and fluctuating loads. The Creep test on metals are to find the metal under steady load.

14. Explain the mechanical properties of materials.

    Mechanical properties are whose characteristics of material that describe its behavior under the action of external forces.

15. Distinguish between elasticity and plasticity.
    - Elasticity is the property of the material by virtue of which it is able to retain its original shape and size after the removal of load.
    - Plasticity is the property of the material by virtue of which a permanent deformation takes place whenever it is subjected to the action of external forces.

16. What are the factors affecting mechanical properties?

    Grain size, Heat treatment, Atmospheric exposure, Low and high temperature.

17. Define the terms Slip and Twinning.
    - Slip may be defined as the sliding of blocks of the crystal over one another along definite crytsollographic planes called Slip planes.
    - Twinning is the process in which the atoms in a part of a crystal subjected to stress, rearrange themselves so that one part of the crystal becomes a mirror image of the other part.

18. Differentiate between ductility and malibility.
    - Ductility is the property of the material by virtue of which it can be drawn into wires before rupture takes place.
    - Malleability is the property of the material by virtue of which it can withstand deformation under compression without rupture.

19. Define the terms brittleness and hardness.
    - Brittleness is the property of the material by virtue of which it can withstand deformation under compression without rupture.
    - Hardness is the property of the material by virtue of which it is able to resist abrasive indentation, machining, scratching.

20. What do you mean by toughness and stiffness?
    - Toughness is the property of the material by virtue of which it can absorb maximum energy before fracture takes place.
    - Stiffness is the property of the material by virtue of which it resists deformation.

21. List any four technological properties of metals.

    Machinability, Castability, Weldability,Formability or Workability.

22. What is meant by fracture?

    Fracture is the mechanical failure of the material which will produce the separation or fragmentation of a solid into two or more parts under the action of stresses.

23. List the different types of fracture in a material. Brittle Fracture, Ductile Fracture, Fatigue Fracture, Creep Fracture.
24. What are the factors affecting the creep?

    Grain, Thermal stability of the micro structure, Chemical reactions, Prior strain.

25. List some important destructive tests carried out on a material.

    Tensile test, Impact test, Fatigue test, Bend test, Torsion test, Creep test.
26. Define the term notch sensitivity.

    The notch sensitivity refers to the tendency of some normal ductile material to behave like brittle material in the presence of notches.
27. Define endurance limit in fatigue test.

    Endurance limit is defined as the value of stress below which the material will not fail even when it is loaded for infinite no. of cycles.
28. What are the properties are determined from tension testing of metallic products?

    Limit of proportionality, Yield strength, Maximum tensile strength, Breaking strength, Percentage elongation and Modulus of elasticity
29. How will you express the deformation characteristics of a material through tension test?

    The deformation characteristics of a material through tension test expressed as the stress- strain curve. With the help of stress strain curve, the various tensile properties such as elastic stress, strain yield strength, young’s modulus, etc are calculated.
30. Why are impact specimens notched?

    The impact specimens are notched because the impact test also indicates the notch sensitivity of a material. The notch sensitivity refers to the tendency of some normal ductile materials to behave the like a brittle material in the presence of notches.
31. What are slip bands?

    Slip bands are made up of several slip planes. They indicate that the atomic planes within the crystal have sheared with respect to each other.
32. Explain in detail Creep.

    The creep is defined as the property of material by virtue of which it deforms continuously under a steady load. Engineering materials are subjected to a constant stress for prolonged time. This would increase the length even though the stress remains constant. This phenomenon of slow and progressive deformation of a material with time at constant stress is called creep.
33. What are the different types of loadings available for fatigue testing?

    Shock or impact load, Static load Random load, Repeated or reversed load.
34. Generally creep rate in the secondary creep region is a constant with time. Why?

    At this stage a balance exists between the rate of work hardening and rate of softening because of recovery or recrystallization.
35. What is “Resilience”?

It is the property of material which enables it to store energy and resist shock and impact. It is measured by the amount of energy that can be stored in a body up to the elastic limit.

36. Explain the term Fatigue.

Components with alternating loading [alternate loads of compression and tension lowers the fracture stress of the material. Such a premature failure is called as Fatigue.

37. Define ductile fracture.

In ductile materials fracture takes place after the considerable amount of plastic deformation. Fracture with considerable amount of plastic deformation is known as ductile deformation.

38. What is critical resolved shear stress?

All metals of similar crystal structure slip on the same crystallographic planes and in the same crystallographic directions. Slip occurs when the shear stresses resolved along these planes reaches a certain value. This is called as critical resolved stress.

39. Define endurance limit(SN).

Materials subjected to cyclic loads (Alternative) the maximum stress amplititude which can be sustained for a given number of cycles (N) is known as endurance limit SN

40. Write the factors which contribute to the onset of fatigue failure.

Corrosion, Surface finish, Temperature, Micro-structure of an alloy, Residual stresses, Stress concentration, Heat treatment.

41. Differentiate between Brittle fracture and ductile fracture.

Sl.No	DUCTILE FRACTURE	BRITTLE FRACTURE
1.	Material fractures after plastic deformation and slow propagation of crack	Material fractures with very little or no plastic deformation .
2.	Fractured surfaces are dull or fibrous in appearance	The fractured surfaces are crystalline in appearance.
3.	Percentage elongation is about 30% before fracture occurs.	Percentage of elongation is approx.0.5%
4.	There is reduction in cross sectional area of test piece	No change in the cross sectional area.
5.	Fracture takes place after necking with little sound.	Fracture occurs rapidly often accompanied by loud noice.

42. Write the difference between Slip and Twinning.

Sl.No	SLIP	TWINNING
1.	All Atoms in one block move the same distance	Atoms in each successive plane within a block move different distances.
2.	Under Microscope: Slip appears as thin lines.	Twinning appears as broad lines or bands.

3.	There is very little change in lattice orientation, of slipped region.	There is a markedly different lattice orientation in the twinned region.
4.	Slip requires less shear stress than twinning	Requires higher shear stress than slip

43. What are the factors, which affect the creep resistant materials?
    1. Pre-strains increase the creep rate.
    2. Substitutional solid solution usually improves creep résistance.
    3. Precipitation and dispersion hardening improves the creep.
    4. Grain size and grain boundaries.
44. Describe characteristics of creep resistant material.
    - Instantaneous extension produced as soon as the test load is applied.
    - Primary or transient creep stage during which further work-hardening occurs.
    - A steady state or secondary creep during which the work-hardening effect of plastic deformation is balanced
    - A period of acceleration or tertiary creep leading to eventual fracture.
45. What are the advantages of pyramid indenter over other indenters?

    One can measure the square or diamond- shaped impression easily as compared with a circular impression. The ends of the diagonal are much sharper under the microscope than the opposite sides of a circle

14 marks

1. Describe a Brinell hardness test to determine the hardness of a metal.
2. Explain the procedure for performing the Rockwell test.
3. Explain the Izod test and charpy test to determine the impact strength of a material.
4. Write an engineering brief about the creep test?
5. Explain the mechanism of plastic deformation of metals by slip and twinning?
6. Describe the characteristics of ductile fracture and brittle fracture.
7. Explain the testing procedure for Vickers hardness testing?
8. Explain the two modes of plastic deformation in metals with neat sketches?
9. What is brittle fracture? Explain the Griffith theory on brittle fracture and deduce an expression for the critical stress required to propagate a crack simultaneously in a brittle materials?
10. Critically compares the deformation by slip and twinning?
11. Explain the types of impact tests and how ductile to brittle transition is occur with diagram.
12. Draw the engineering stress – strain curve for mild steel, aluminium and cast iron. Discuss the tensile test and different mechanical properties obtained in tensile testing. Write a short note on compression test.
13. Discuss fatigue test for a metallic material. What is S-N diagram?
14. What are the different types of fractures in metallic materials? Give the important features

of these fractured surfaces. What is the use of this study?

15. What are the properties measured from tensile testing and write their engineering significance? Draw the stress and strain curve for aluminium, cast iron and low carbon steel.
16. Describe fatigue testing and methods for improving fatigue strength of the components.
    Draw the S-N curve for aluminium and titanium.
17. Draw creep curve and explain the different stages of creep damage.
18. Draw S-N curve for ferrous and non-ferrous metals and explain how endurance strength can be determined. Also discuss the factors that affect the fatigue life.