TurboIEG.com

ملخص المانيوال :

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Material Lab

للطالبة : دانية اسماعيل

اللجنة الأكاديمية لقسم الهندسة الصناعية

2023

- Materials
  - woods
    - Hardwoods
    - Softwoods
    - Manufactured boards.
  - Polymers
    - Thermoplastics
    - Thermosets
  - metallic materials
    - metals
      - ferrous → Iron.
      - non-ferrous
    - metal alloys
      - ferrous → Iron.
        - Steels
        - Cast Iron
      - non-ferrous

Metals & metal alloys → identified → by numerical index system

- from it
  - class
  - Predominant alloying agent
  - average carbon content %
- are given

if NIS is not known → several methods used To identify metals & Thier alloys.

methods:

- surface apperance
- spark test
- chip test
- use of a magnet
- color
- distinctive marks left from manufacturing.

Utilize Properties:

- magnatic Properties
- density
- heat capacity
- corrosion resistance
- spark apperance.

- Steels
  - Carbon steels
  - alloy steels
  - stainless steels.

Steels classified based on their chemical composition

- Cast Iron & Cast steel have seperate specification numbering system.

Carbon steels

Low carbon steel

0.05-0.3% carbon

used in automobile body Panels, Tin Plate, & wire Products

0.3% carbon

↳ Mild steel

↳ used in nuts, bolts, screws, Tubes, griders.

Medium carbon steel

0.3-0.6% carbon

used in shaft, axles, gears, Crankshafts, couplings, forgings.

0.4-0.6% C

↳ used ~~in~~ for rails, railway wheels & rail axles.

High carbon steel

0.6-1% C

used for spring materials and high strength wire.

$\boxed{\text{Ultrahigh-Carbon steels}}$ →

- experimental alloys
- 1.25-2% C
- Thermomechanically processed to produce microstructure that consist of ultrafine, equiaxed grains of spherical, ~~[illegible]~~ discontinous proeutectoid carbide Particles.

Alloy steel → adding elements to improve the Properties of the metal for specific applications.

↳ elements: carbon, copper, sulfur, manganese, Phosphorus, chromium.

< 8% from element

↳ Low alloy steel

> 8%

↳ high alloy steel.

$\boxed{\text{> 3.99\% Chromium ↳ stainless \& tool steels.}}$

SAE-AISI system carbon & alloy steels

4 - digits.

Carbon concentration in hundredths of a percent

for carbon steel
↳ modification of the steel

- 0 Plain carbon steel (max 1% Mn) — non modified
- 1 Resulfurized
- 2 Resulf & Rephosphorized
- 5 Non-Resulf, 1% < Mn < 1.6%

↳ but for alloy steel
↳ the 2nd digit
↳ Concentration of the major element in percents.

a Letter Prefix
↳ indicates the steel making technology

steel grade
1 C-steel
2 Ni-steel
3 Ni-chrom steel
4 Molybdenum steel
5 chrom steel
6 chrom-vandinum steel
7 Tungsten-chrom steel
9 silicon-manganese steel.

A → Alloy, basic open hearth
B → C, acid Bessemer
C → C, basic open hearth
D → C, acid open hearth
E → Electric furnace.

Stainless steel → 4 groups

based on thier crystalline structure.

① austenitic ② Ferrite ③ martenstic ④ precipitation hardening.

- Carbon (0.03% to 0.45%)
- chromium (11% - 32%)
- nickel (0.6% - 37%)
- molybdenum (0.35% - 4%)
- manganese, Phosphorous, silicon, sulfur, copper — smaller amounts.

• digits of stainless steels:

2XX ~~cr-Ni~~ cr-Ni-Mn-①
3XX cr-Ni-①
4XX cr-③ or ②
5XX Low cr-③
6XX cr-④

Tools steels

- Capable of being hardend & tempered.
- have more alloying elements → elements: chromium, Tungston, molybdenum, vanadium, cobalt.
- different by the why They are manufactured
- have 6 major categories.

فرقهم عن ال carbon و ال alloy steel

• Types

→ Cold work
- → W: water hardening
- → O: oil hardening
- → A: Air hardening (medium)
- → D: high carbon, High chromium.

→ shock resisting → S

→ Hot work → H

→ High speed
- → M: molybdenum
- → T: Tungusten
- ↳ have more than 7% alloy content & more than 0.6% C

→ Mold steels → P

→ special purpose → L & F series.

• Cast Iron

2% - 4% C

→ Low melting Point

→ good fluidity

→ good castability

→ excellent machinability

→ resistance to deformation.

→ wear resistance

→ Brittle ~~except for~~ except for malleable cast iron.

classified by color of fractured surface

- white
  - malleable ↳ by heat treatment of white cast iron.
- grey
  - Nodular (ductile)

• Aluminum alloy

↳ 4 digits

- first → major alloying element
- second → modifications, Zero → original
- last 2 digits → different Al alloy ↳ in common commerical use except in 1xxx

Non heat treatable	heat treatable
1xxx	2xxx
3xxx	6xxx
4xxx	7xxx
5xxx	

Tests → distractive test يدمر العينة
→ undistractive test لا يدمر العينة

1 Color test

Brass → yellow
↳ copper + Zinc
Zn ↑ → أكثر اصفرار

Aluminum → silver

~~Carbon~~
steel → gray
↳ Carbon + Iron
C ↑ → أكثر سواد

Medium carbon steel → Dark gray

Low carbon steel → light gray

2 density test

$$D = \frac{Mass}{Volume}$$

Mass → بنوزنها عن طريق ال electric scale

Volume → شكل منتظم → قانونه
→ غير منتظم → باستخدام الماء

V (الماء والعينة) - V (الماء) = V (العينة)

بنحسب ال density وبنجيبها من الجداول.

3 Magnatic test

الجهاز المستخدم
electrical magnatic york

materials →

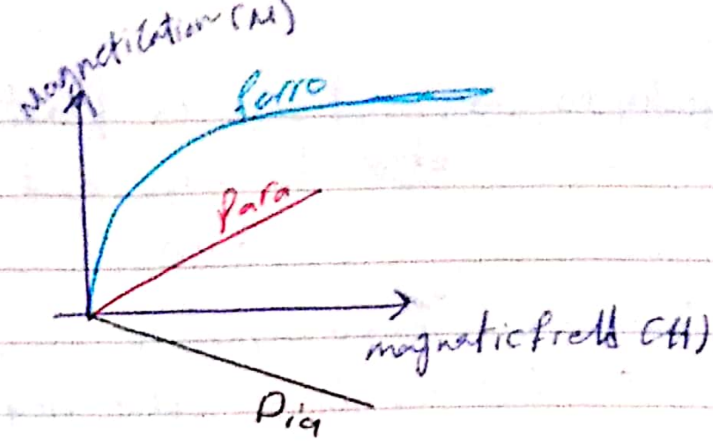
1. Ferromagnatic
↳ large & +
↳ بتجذب المجال المغناطيسي وبتحتفظ فيه.
ex: iron cobalt nickel
↳ عندهم small domains
↳ لما نحط external magnatic
↳ N ← ← ← S
بتعكس اذا ال external magnetic.
↳ اذا بعدنا ال external
↳ the metal becomes a Permanent magnet.
↳ Curie temperature
↳ essential for ferromagnatic
↳ temp < Curie
↳ still ferro
↳ temp > Curie
becomes Paramagnatic or does not become a magnet.

2. Paramagnatic
ex: Al, magnisum, platinum
↳ small & +
↳ تنجذب ولا تحتفظ
needs very large magnet
when removed
↳ no permanent effect remains.

③ diamagnetic

↳ ex: copper
lead
silver

small & ⊖



$$\boxed{M = XH}$$

• Cold work

↳ generate strains in the material that will make them at least slightly magnetic.

④ specific heat

↳ the amount of heat per unit mass required to raise the temperature by one degree celsius.

عند ثبات النظام

$$M_w * \Delta T_w * C_{pw} = -M_s * \Delta T_s * C_s$$

$T_w = T_s$ $\qquad$ C_{pw}: 4.18 KJ/Kg.K $\qquad$ ΔT_s: $T_2 - T_1$

$Q_w = Q_s$

استخدم ميزان الحرارة mercury thermometer

تم حساب الكتلة بالميزان الإلكتروني

نقل حرارة معينة ودرجة حرارة latent heat

اللي هو الطاقة بتحول الماء لبخار.

لازم ما نتعدا حرارة النظام الـ 90°C لحتى ما نشوف الـ latent heat

لما ننقل العينة من الفرن للماء ← تنقل حرارة تغير منيح ← عشان

هيك في فرق بين الـ actual

Hardness → resistance to plastic penetration, ~~abs~~ abrasion and scratching of its surface.

hardness measurements:
1. → scratch hardness (the simplest).
2. → indentation " (BH, R, K, V)
3. → rebound, or dynamic "

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1 → ability of the materials to scratch one another.
HM: (Mohs Test) used in mineralogy.
↳ "Compare".
↳ 10 minerals. 1 talc (softer).
10 diamond (harder)

The scale is arbitrary. (not linear).
↳ & relative scale.

can be used in body powder.

most hard metals → from 4 to 8.

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2 → based on the relation of indentation of specimen by a penetrator under a given load.

Brinell → indentor: hardened steel or $\boxed{\text{Tungsten carbide}}$ ball

used to minimize distortion of the indenter when testing very hard material.

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

F → kg, D → mm, d → mm

$= [kg/mm^2]$

Time: soft → 10-15 sec
hard → at least 30 sec.

Load: 3,000 kg
but for soft materials
↳ 1,500 or 500
to avoid excessive indentation.

~~Time : 10 to 15 sec (for soft) at least 30 sec~~

diameter: 2.5 - 6 mm

low powered microscope
↳ [illegible]

150 HBS 10/3000/30 ← مثلا • طريقة كتابة BHN

- 150 → BHN
- HB → Brinell Hardness Test
- S → بطلع S or W
  - steel ball
  - Tungesten Carbride ball (wolfram)
- 10 → d of ball in mm
- 3000 → Load in Kg
- 30 → Time in sec

• لما يكون أكبر أو أصغر, لازم $\frac{d}{D}$ و $\frac{P}{D^2}$ يكونوا constant.

• BH ← بالعادة للـ large parts
لأنه لما تعمل indentation بيكون الـ deepest والـ widest.

• للـ steel في الـ BH اللي أكبر من 500
↳ Vickers test is more reliable.

Rockwell → diamond cone (brale) or hardened steel ball.

2 Loads → minor F_1 → Press the indentor into the surface.
→ major F_2

$$HRN = E - e$$

- E → constant of 100 unit for diamond & ball
- e → Permanent increase in length measured in 0.001 mm.

• فيه scales للـ Test from A to H
↳ The most common B & C

HRB
- softer steels & Brass
- 1/16 in. steel ball
- 100 Kg major
- RB 0 to RB 100

HRC
- for hardened steel
- diamond
- 150 Kg major
- RC 20 - RC 70

→ الأكثر استخداماً why?
speed, freedom of personal error, ability to distinguish small hardness, small size of indentation, the finished heat parts can be tested without damage.

- Rockwell depends on depth.
- in Rockwell → Thickness be at least 10 times the depth.
- spacing should be 3 to 5 times the diameter
- below HRC 20 → unreliable.
  above 100HRB → "

Vickers → square Pyramidal diamond

4 Kg - 120 Kg   15 sec

Pyramid shaped indentation

$$HV = 1.854 \frac{F}{d^2}$$

d^2 ↳ average of diagonals.

⊠ d_1 & d_2 → measured under a microscope
"diagonal"

$\underbrace{800}_{\text{قيمة}}\ \underbrace{HV}_{\text{Vickers}} / \underbrace{10}_{\text{Load}}$

→ advantages
accuracy ↑ in determining the diagonal of a □ as opposed to the diameter of a circle

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Knoop → rhombic-based Pyramidal diamond

10 g – 1000 g   axis ratio 7:1
130° & 172°

↳ needs a Polished test surface (mounted & Polished)

magnification X500

$$HK = \frac{F}{CL^2}$$

F → Load
C → correction factor 0.07028
L → Length

- suitable for thin plastic sheets, thin metal sheets, brittle materials, material where the applied load must never exceed 3.6 Kg.

for steel

$\sigma_{UTS} = 0.35 * BHN$

$\sigma_y = 3.2 * HV$

Dynamic testing (Leeb test)
(Rebound).

$HL = (VR / VI) * 1000$

VR → rebound velocity

VI → initial velocity.

العينة الصلبة ← لا تمتص طاقة من الكرة.

ترتد الكرة ← العينة صلبة

من خلال الصوت وسرعة ارتداد الكرة..

العينة الغير قاسية ← تمتص طاقة ← ترتفع الكرة مرة واحدة بالأكثر.

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exp3 crystallographic planes & directions.

• Miller indices used to express lattice planes & direction.

[ ] → for direction   ( ) → for plane

< > family for direction   { } → family for plane

or [[ ]] بتساوى بالطول   or (( ))

• Parallel planes have تساوي اطوالها same miller indices

• اذا الشكل مربع او مستطيل لما يطلع معك صفر او صفرين.

• اذا مثلث ← غالبا في ارقام.

Polymers → often amorphous
metal & ceramics → " crystalline.

• properties → determined by type of structure & atomic bonding.

~~structure~~ • Close packing → most efficient way to fill space.

→ single layer of spheres is closest packed with a hexagonal coordination of each sphere

• لما نحط ~~Vacancy~~ second layer ← بيصير يطلع عنا فراغات صغيرة.

بين ال atoms ال layers

↳ Called Interstitial sites.

Tetrahedral   octahedral → هو سطحه النوعين لما ال largest

ABA
ABC ← اصلا الترتيبين ← بيصير عنا ← third layer • لما نحط

• in close packed structure
↳ coordination number is $\boxed{12}$
↳ 74% of space is occupied

$\boxed{SC}$ → # of atoms = 1
cordination = 6
only Po (Rare because of low Packing density).
closed Packed direction $\square$
$a = 2R$

$\boxed{BCC}$ → Cr, W, Fe(α), Ta, Mo

Chromium, Tungesten, Molybdenum, Tantalum

18 octahedral
24 tetrahedral

# of atoms → 2
cordination → 8
closed Packing → قطر المكعب
$4R = \sqrt{3}\, a$

$\boxed{FCC}$ → Al, Cu, Au, Pb, Ni, Pt, Ag

Copper, Gold, Lead, Platinum, silver

13 octa
8 tetra

coordination → 12
# of atoms → 4

close packed → قطر المربع

$\boxed{HCP}$ → 2 lattice Parameters. a & c
a → bassal, c → hieght
$c/a = 1.633$

6 octa
8 tetra

# of atoms = 6
APF = 0.74
coordination = 12

Doping forming → محلول صلب بدائل
(doping alloy)

عنصر أول (مضيف) + عنصر ثاني (مضاف).

• ممكن نسمي ال doping نفس اسم ال alloy

• ما نقدر نسمي ال doping لل composite

exp 4

sample preparation.

Metallography : study of material microstructure using microscopic techniques

الفوائد أو الإستخدامات → Process control, examination of defects and studies of parts that have failed

method to examine structure ⇒ optical technique.

- small parts & we need more than one sample

scale	unite	Level	ex
Millimeter	$\times 10^{-3}$ m	Macro	seen by naked eye.
Micrometer	$\times 10^{-6}$ m	Micro	Blood cells.
Nanometer	$\times 10^{-9}$ m	Nano	Atoms, DNA for ex 2nm wide
Angstrom	$\times 10^{-10}$ m	Nano	unit cell parameter.

خطوات تحضير العينة ←

1. sectioning, cutting
2. Mounting
3. Grinding
4. Polishing
5. Etching
6. Microstructure examination.

1. sectioning, cutting

→ حتى نصغر حجم العينة اذا لزم.

في أكثر من طريقة

- Mechanical
  - ~~Cut of wheel~~ abrasive cutting
    - Cut of wheel — most common
  - cutting
    - Lathe خراطة
- Torch
- Arc cutting
- electrochemical
  - ~~acid mit~~ acid milling

method depends on how hard is the material.

حتى لا ترتفع حرارة العينة نضيف سائل تبريد → ارتفاعها يؤدي لتغير structure ↳ microstructure cutting الهدف منه

↳ control samples

↳ suitable size

suitable for other operations

② Mounting

↳ for small samples

↳ to enclose the sample by thermosoftening material

↳ can be done in hot or cold conditions.

→ mounted specimen → Thickness = $\frac{1}{2}$ diameter

↳ to prevent rocking during grinding & polishing.

↳ edges → rounded.

↳ to minimize the damage to grinding & polishing discs.

← يتم تغليف القطعة بغلاف من مادة الـ epoxy بواسطة جهاز ⇐ بيعمل ضغط وحرارة.

القوة ← 0 - 40 Kg بالعادة 25 Kg

Time heating 0-18 min بالعادة 7 min

Time cooling 0-12 min بالعادة 9 min

• درجة الحرارة المستخدمة ←

180 °C or 150 °C

حسب الـ epoxy المستخدم

③ grinding

→ surface آخر إشي بيصير semi-mirror.

↳ الهدف تخفيف الـ scratch.

باستخدام ورق زجاج {← grit paper.

↳ to remove layers caused by cutting.

• منحط ماء أثناء العملية عشان ما ترتفع حرارة العينة

• Coarseness of grit paper indicated by number (عدد grains في الإنش المربع).

كلما زاد الرقم ↓ أنعم

• The paper is Al2O3 / SiC particles.

$\boxed{40 - 150}$ → coarse grit paper

$\boxed{180 - 600}$ → fine.

for cutoff wheel specimen

↳ $\boxed{150 \text{ or } 180}$

for hand sawed بمنشرة

↳ 80 ~~or~~ to 150 mesh

satisfactory grinding sequence

↳ 180, 240, 400, 600 mesh.

بال grinding ← لازم أحرك حوالي نلف العينة 90°
↳ to remove scratch caused by grinding.

(4) Polishing → للتخلص من كل بقايا الـ scratch

قطعة قماش + (1-5) μ of diamond بدل 6μ

↳ 6 Mm particles of diamond to remove all scratching.

result → exactly mirror

(انعكاسة للضوء Reflection) انعكاسة ، بيكون مرايا ، عالي

(5) Etching

↳ subject the mirror sample with acid.

↳ used to reveal the microstructure.

↳ steel → etched by nitric acid (2%) & (98%) methanol

↳ Time : ≃ 10 sec

exp 5

Microscopical examinations

بيتم دراسة ← phase ال, grains ال, grain boundaries ال, constituents ال

• microstructure is determined ~~to~~ based on chemical composition & manufacturing steps.

→ helps to know if the material has been ~~process~~ processed correctly.

→ required → prepared sample & metallographic microscope.

• grain boundaries reflect light at different angles
↳ appear as dark lines.

بعكس ← المبدأ ← ضوء ال reflected light

• opaque materials can be examined.
غير شفاف

• main parts of microscope: eyepiece lenses, → magnification 10 times
objectives lenses, video camera, filters, stage, knop, aperture, field iris diaphragm

objectives lenses → one sided convex lens with its flat side directed to the specime. magnification 100 times.

knop ↳ بنحرك فيها stage ال لفوق وتحت ومن اليمين واليسار

field iris diaphragm ↳ controls the amount of light that passes through the object.

$\boxed{\text{total } M = 1000}$

• بيختلف باللون ← باختلاف phase ال تبعا لاختلاف optical properties ال

• Twin boundaries
↳ when 2 crystals of the same type have only a slight mis orientation between them

NA → characteristic property of an objective (numerical aperture).

$$N.A = n \sin\theta$$

n → magnification

$$r = \frac{\text{wave length}}{2\,N.A}$$

~~reflection~~ resolution

$$R = \lambda / 2n\sin\theta$$

θ: half angle under which light enters the lens from the point in focus.

چی می‌بینیم بعد از etching؟

→ grains & their oriantation

→ phases after heat treatment

→ Twins → Distortion of phases

→ plate thicknes.

- steel
  - martensite appears like needles

- Lamellar is most likely to be pearlite.

E Construction of Phase diagrams

Show the equilibrium state of the alloy.

→ map of an alloy system, indicates which phase should exist under condition of equilibrium for any particular combination of composition & temperature.

specific temperature & composition
→ we can predict which phases will be formed & in what quantities.

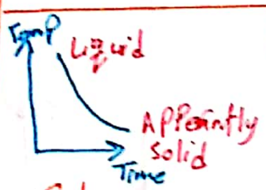
→ important in understanding metallic & ceramic alloys

→ provides the information about the $\boxed{\text{heat treatment processes}}$
→ used to modify the structures & properties of alloy.

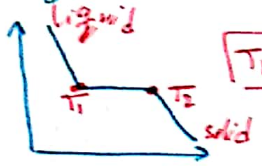
main Theory → based around the latent heat that is evolved when mixture is cooled.

Phase → portion of matter which is homogeneous.

Temperature بين graphs يعني ←
ولـ Time لمجموعة من
الـ different compositions
→ بتخلينا قادرين
نعرف عند أي درجة حرارة
رح تتكون كل phase.

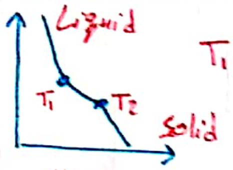


Glassy
"non crystalline"



$\boxed{T_1 = T_2}$

Crystalline
"Pure".



$T_1 \neq T_2$

alloy

Glassy → continuous curve, no definite solidification temp.

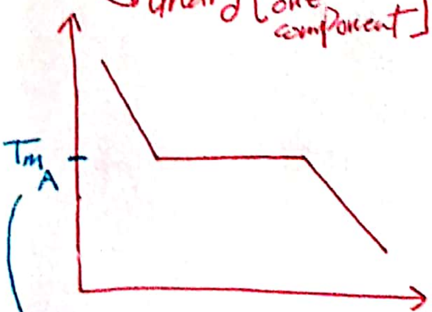
crystalline "pure" → Discontinuous curve, definite solidification Temp.

alloy → solidification over a range $\boxed{T_1} \rightarrow \boxed{T_2}$

T_1 → Liquidus Temp.
→ فوقها liquid كله

T_2 → solidus Temp.
→ تحتها كله solid.

Pure element A
100% A
→ unary [one component]



→ melting temperature (at constant pressure).
→ [L + S] phases exist together in equilibrium.
→ only in T_m.

- At $\boxed{T_m}$
→ Pure element will start to crystallize
- when solidification completes
→ Temperature of the material will start to decrease.

Cooling curve

→ temp. with time.

لـ بيسخنوها لحتى يذوب وبعدين بيبردوها
برد وبيحسبوا الـ Temp و Time.

in alloy

off eutectic composition
↓
do not cross the eutectic temp. line.

Eutectic composition.
↓
has the lowest melting point in the phase diagram.
↓
T_m → called eutectic temp.

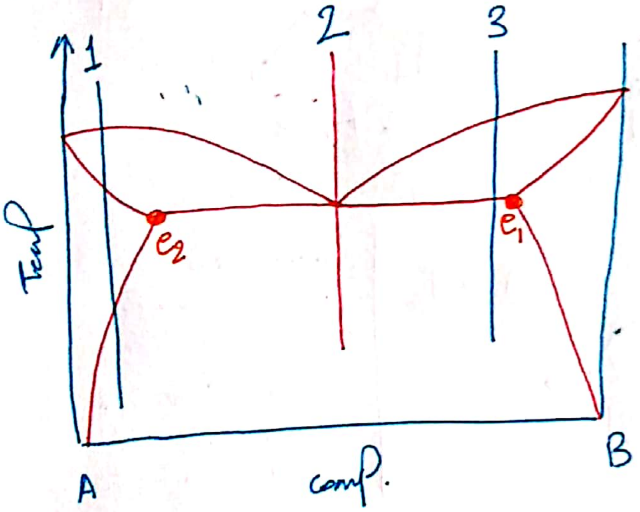
• many alloys → created by mixing substances in liquid state.

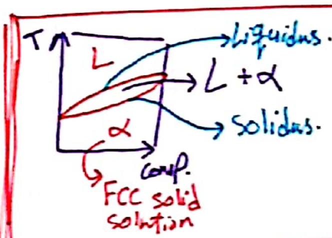
• alloy structure → form by solidification of liquid alloys.

• insolube → Totally. / Partially.

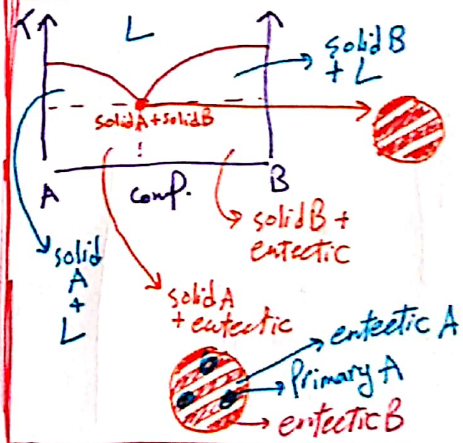
• most alloys → completely soluble in one another.

• if completely soluble in molten state
↳ does not necessarily mean that the ~~liquid~~ it is homogenous solid phase.





"Solid solubility".

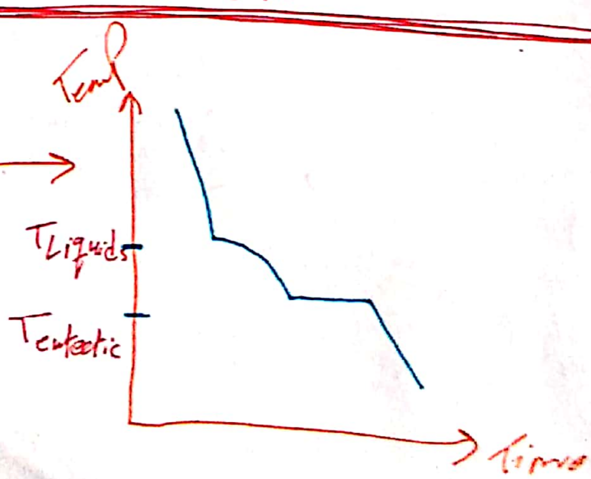


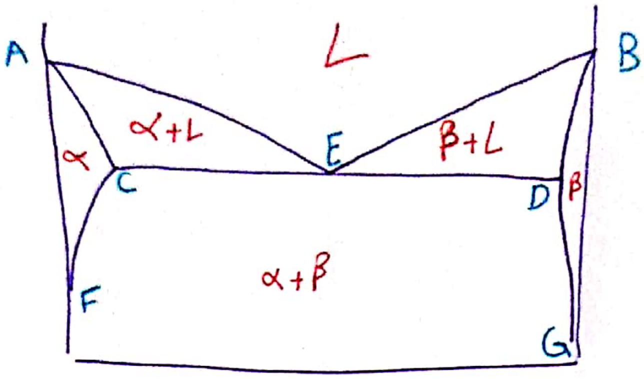
"Total solid insolubility"

2 → eutectic composition

1 → off ~~comp~~ eutectic comp.

$\boxed{3}$ → ~~eutectic comp~~. comp. between e_1 & e_2. →
→ two stages of soldification in cooling curve.





"Partial solid solubility"

AEB → Liquidus

ACEDB → solidus

FC & GD → solvus

FC → solubility of B in A with maximum solubility at C

GD → solubility of A in B with maximum solubility at D

α & β → Solid solutions.