Written by Essa Al-Sharif

* Crystal Structure of Ionic materials:
Ionic material must have Crystal structures that ensure
electrical neutrality, yet ~~presens~~ Permt Ions from the different Sizes
to be Packed efficiently.

① Ionic Radii: the crystal structures of ionically bounded
compound, is described by placing the anion of the normal
lattice point Cell and the cation located at one or more of the
intransitial site.

② Electrical neutrality: the over all material have to be electrical
neutral.

Allotropy: the ability of the element too exist more the one
crystal structure. depending on Temp. & pressure.

Polymorphism: Compound have more the one crystal structure.

Chapter 4

* "Crystals are like people it is the defect in them
which tend to make them interesting" Colin Humphry.

* Defect in Solids 0 D, Point defect. [zero]
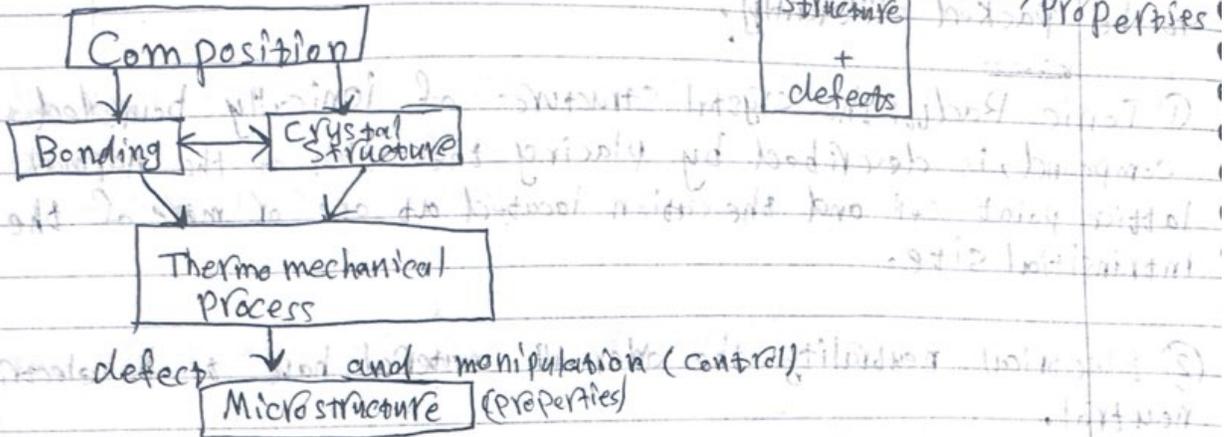
- Vacancies
- Intransitial,
- Impurities.

1-D: , edge   screw   edge + screw

2-D: Surface defect

3-D: Volume defect

Defects:

The process determines the defects

Bonding
Structure
+
defects

→ Properties

Composition
↓
Bonding ← → Crystal Structure
↓   ↓
Thermo mechanical Process
↓
defect and manipulation (control)
Microstructure (properties)

① Point defect: atoms missing or an irregular places

② 1-D: group of atoms in irregular position
③ 2-D: Interfaces between regions of material (grain boundaries)   interfaces
④ 3-D: Vacks   ٌثقوب

Vacancies: is produced when an atom is missing from a normal site.

* the number of Vacancies increas exponentially as increase the Tempretoure

$$n_v = n \exp\left(\frac{-Q}{RT}\right)$$

n_v: is the number of Vacancies per m^3.
n: = 〃   〃   〃   Lattice points ÷ m^3.
Q: is the energy required to produces a vacancy in $J \cdot mol^{-1}$

R: is the gas constant

$$R = 1.987 \frac{Cal}{mol.K} \quad ; \quad R = 8.314 \frac{J}{mol.K}$$

T: Temprature (K).

Ex: Copper
$$Q = 83700 \, J.m^{-1}$$
Copper: FCC   (Aluminum so too)
Lattice parameter = 0.36161 nm
Suggest a heat treatment that will provide 1000 times more
Vacancies in copper.

$$n = \frac{4 \text{ atoms/cell } (Fcc)}{(0.36161 \text{ nm})^3} = 84.6 \quad T = 25 + 273 = 298 \, K$$

درجة حرارة الغرفة

$$n_v = n \, e^{\left(\frac{-Q}{RT}\right)}$$

$$n_v = 1.774 \times 10^{14} \, vaca/m^3 \qquad n_v = 8.46 \times 10^{28} \, e^{-\left(\frac{83700}{(8.314)(298)}\right)}$$

$$\text{New } n_v = 1.774 \times 10^{17} = (\quad) \exp\left(\frac{-83700}{8.314 \, T}\right) \qquad n_{v_1} = 1.8 \times 10^{-13}$$

$$\Rightarrow T = 375 \, K = 100 \, c°$$

Ex: Calculate the # of vacancies per cm^3 in copper at 1088c
(Just below the melting point temp). The activation energy for vacancy
formation is 20000 Cal/mol.

$$a = 3.6151 \times 10^{-8} \, cm$$

$$n = \frac{4}{a^3} \qquad n_v = 4.97 \times 10^{14} \, vac/cm^3$$

التدرج في تغيير درجة الحرارة يأثر
بالتبريد مع جرأة لأنل يبدد
ولد يتبرد شوي شوي

Ex: The fraction of lattice points occuped by vacancies in solid Al at $660°$ is 10^{-3}. What is the activation energy required to creats vacancies?

$$n_v = n \exp\left(-\frac{Q}{RT}\right) \quad , \quad \frac{n_v}{n} = 10^{-3}$$

$$Q = 12.800 \ Cal/mol$$

Ex: ρ of a sample of an FCC metal is $11.98 \ g/cm^3$ and the lattice parameters is $3.8902 \ A°$. Calculate: Atomic weight$= 1.064 g/m$
ⓐ the fraction of lattice points that contain vacancies.
ⓑ The total number of vacancies in cm^3.

x: number of atoms
↓
real

4 قيمة FCC خلايا

ⓐ $\rho = \dfrac{(x)(1.064 \ g/mol)}{a_0^3 \ (Avogadro)}$

$$x = 3.9905$$

$$fraction = \frac{4 - 3.9905}{4} = 0.0023 \times 5$$

\# of Vacancies $= \dfrac{0.0095 \ vacancy/uc}{(a)^3}$

$$= 1.61 \times 10^{20} \ Vac/cm^2$$

Ex: BCC metal has an $a = 3.5089 \times 10^{-8} \ cm$ and contains one vacancy per 200 unit cell. Calculates $Aw = 6.94 g/mol$
ⓐ \# of Vacancies /cm^3.
ⓑ ρ.

ⓐ $\dfrac{1 \ vac}{200 \ (a_0)^3} = 1.157 \times 10^{20} \ Vaca/cm^3$

ⓑ $\rho = \dfrac{(399/200)(6.94)}{(a_0)^3 \ Avg}$

Ex: unidaium alloy is produced by introducing tungston Substational atoms (in BCC) structure eventually an alloy is produced that has an $a = 0.32554$ nm & $f = 11.95$ g/cm^2. Calculate the fraction of the atoms in alloy that are tungeston.

$$11.95 = \frac{(X)(183.85) + (2-X)(92.91)}{(a_0)^3 (A_{vog})}$$

$X = 0.69$ atom/cell

2 atom Per cell in BCC

$frac = \frac{0.69}{2} = 0.345$

slide 20:

زنوتا

اذا كان فيه عيوبي انحراف ن ... ن للزم اللوب يكسر

البيروفكار فاكتور بكونه موجود احنا بي كون تـــه هو عبارة عن الفراغ

مؤشر ادبش في انحرافن

☐ perfect

الفدرس هي ما نكورا ال edge او ال screw

Critical resolve sheer stress:

Schmid's Law:
is used to understand the differences in behaviour of metals that have different crystal structures by examining the force required to initiate the slip process. من خلاله بعرف القوة اللي بتحتاجه slipping أما بتجاوزها

$fr = f \cos \lambda$

$6 = \frac{f}{A_0}$

$A = A_0 / \cos \emptyset$

$$\boxed{\tau_r = 6 \cos \emptyset \cos \lambda \quad (\text{Schmid's Law})}$$

normal to slip plane

shear stress

A

A_0
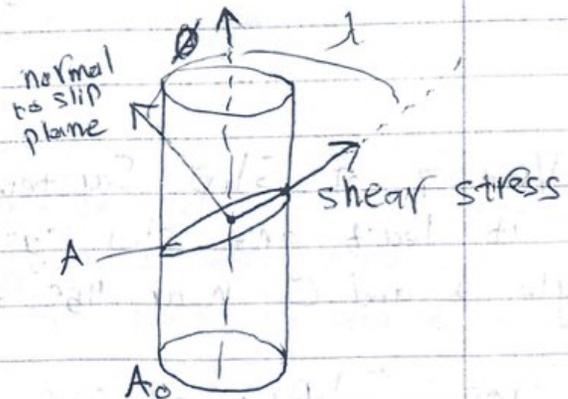
$\tau_r = \frac{fr}{A}$ = resolved shear stress in the slip direction.

$\sigma = \frac{f}{A_0}$ unidirectional stress

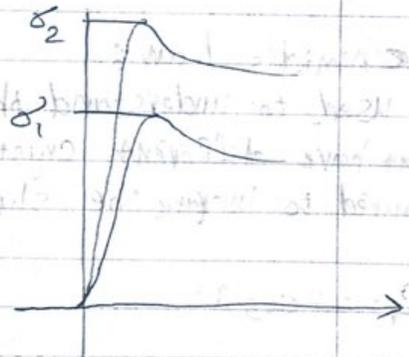Influence of Crystal Structures :
① Critical Resolved Shear Stress (CRSS)   بجوة الشغ
★CRSS: The stress Required to cause dislocation to move and
cause Ē slip

★ If the CRSS in a metal is Very high the applied
stress (σ) must be high in order for τr to equal τcrss°
A higher τcrss Implus a higher stress to Plastically deform metals
where a higher strength.   اذا بدي احمل تشكيل بلي اكبر او بساوي
                                           اذا كانت τ اكبر τcrss بلي اقوى.

BCC	FCC
higher strength	lower strength
ductility low	ductility high

لانه في ذرات كسر عندي
مدية يقدر اسحب بدنا كسو

Strain hardening   التقوية بال   .
ductility الـ لما سحبناها زدنا القوة بس   عالية
                         دمار, عندي منشأت عاليه

② Number of Slip System:
if at least one slip system is oriented to give the
angle λ and Ø near 45° then τr = τcrss at low stress

③ Cross Slip: when screw dislocation moving on one slip
Plane that encountres on obstcals and blacked from further
movement
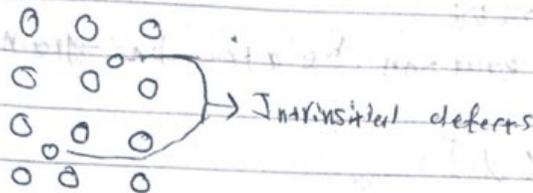∴ the dislocation can shft to a second intersection slip Section
this is called cross slip.   تولد تنفيذها تشابه من اسحب

Vacancy defects:

## Intrinsitial defects:

→ Intrinsitial defects

Burger Vector: slide 27

If we follow a crystallographic plans one revolution around the axis on which the crystal is skewed, starting at point (X) and traveling equal atom spacing in each direction, we finish at point (Y) one atom below our starting point if the screw dislocatic not present the loop would be close.

The vector required to close the loop is called (Burger vector)
b - vector
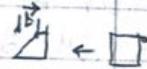
Importance of Defects:

① effect on mechanical properties via control the slip process. One imprefaction in the crystal raises the internal energy at th location of the improfaction.

* the local energy increased because near the imprefuction the atoms either are squesed to closely (compresion or forced too far apart (tension).

② Strain Harding: هو اللي بطلع احمل ← حبة defect.

③ Solid solution strengthing.   ذرات نتقل من مكان لتخر لكن في الحالين one of the point defect also disrupt the perfecation of crystal structure solid solution is formed when atoms or ions are assiumilatee completely into the crystal structure of the host material.

Toughness: the ability to absorb energy
Hardness: resistance of indentation
brittle: material has a little plastic deformation
④ grain size strengthening.

Surface Defect:
Hall-Petch equation Relates the grain size of the Y strength

$$\sigma y = \sigma_o + K d^{\frac{-1}{2}}$$

σy: Y. strength
d is the average diameter of the grains.
σ_o, K are constant for material.

Specification of grain size:
$$N = 2^{n-1}$$

N: number of grains per in^2 at magnification X 100
n: ASTM grain size.

Ex: Copper 2 in alloy has the following prop.

grain diameter	strength	$d^{-1/2}$
0.015	170	8.165
0.025	159	6.325
0.035	151	5.345
0.05	145	4.472

Determine:
① the constants in the Hall-Patch eq.
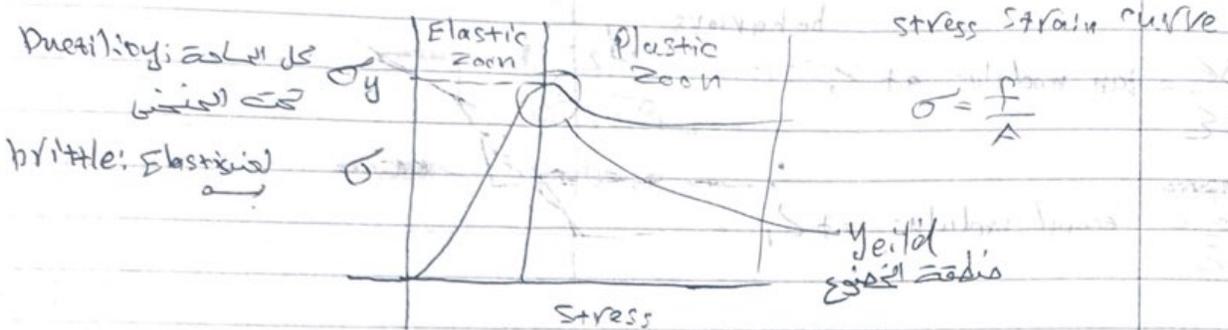② the grain size required to obtain the strength of 200
① K= 6.77
σ_o = 114.7

بنين بمعادلات نقطتين بنطلع σ_o, K

② $200 = 114.7 + 6.77/\sqrt{d}$
   ⇒ d =

Chapter 6

Ductility: قابلية المعدن للتمدد تحت تأثير الضغط σ_y

brittle: Elastic قصيف σ

stress strain curve

$$\sigma = \frac{F}{A}$$

Elastic Zoon | Plastic Zoon

Yeild تحدث النقطة

Stress

Engineering Stress: $\sigma = \frac{F}{A}$

Strain: $\varepsilon = \Delta L / L_0 \; (\times 100\%)$

$\sigma, \varepsilon \; (+) \; T$

$\sigma, \varepsilon \; (-)$

material

Brittle   Ductile
قصيف   طري
التربط بالأيونيات

Shear stress: $\tau = \frac{F}{A_0}$

$\varepsilon_B \; > \; \varepsilon_D$

Shear strain: $\gamma = \tan\theta \; (\times 100\%)$

$\sigma_B \; < \; \sigma_D$

Stress - Strain behavior

σ_y Elastic Plastic

P

0,002 ε

L_0 L

$$\sigma = E\varepsilon$$
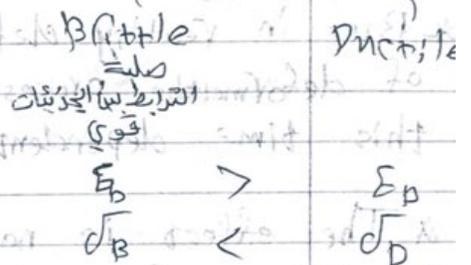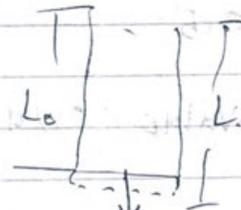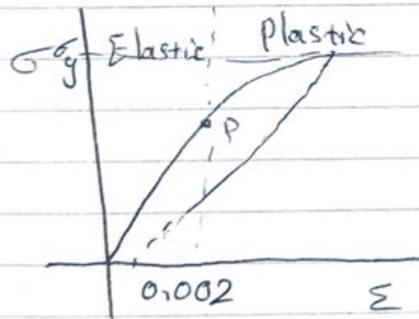
Strain(ε): change in the length , deflection= $\Delta L = L - L_0$

$\sigma = \frac{F}{A}$, $\frac{\delta}{L} = \varepsilon$, $\sigma = E\varepsilon$
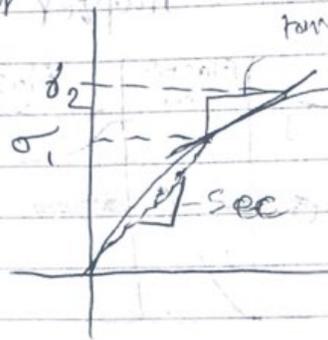
stress   strain
specific for material
modulus

non-linear
behaviors

$\dfrac{\Delta 6}{\Delta \varepsilon}$ = tan modulus at 6_2

$\dfrac{\Delta 6}{\Delta \varepsilon}$ = Second modulus at 6_1

Anelasticity: الوقت مهم في هذا اليوم سبب (المدة)
time dependence of elastic deformation.

* we have assumed that elastic deformation is time independent.

* But in reality deformation takes time (limit rate of deformation processes).
this time dependent elastic behavior is known as anelasticity

* The effect is normally small for metals but it is significant for polymers

Poisson's Ratio:

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}$$

max = 0.5

Typical value: 0.24 - 0.3

$\sigma_x = 0$ $\sigma_y = 0$ $\varepsilon_z \neq 0$ Plain stress   plain strain   ?؟
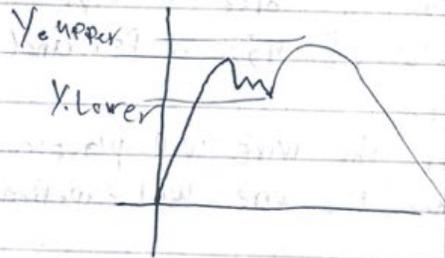
* Plastic Deformation:

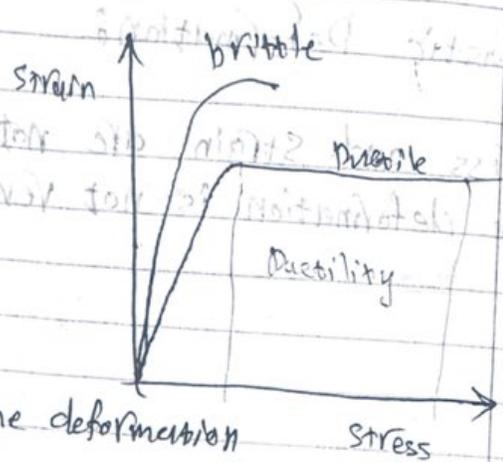* Stress and strain are not proportional.
* the deformation is not reversible
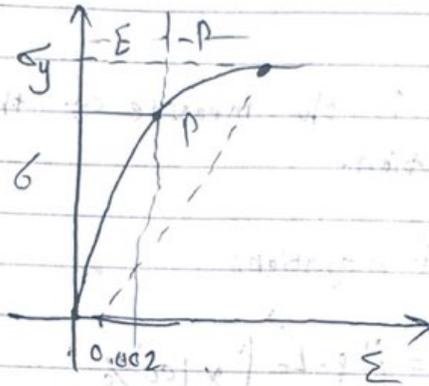
σ_y = Y. strength; is chosen as that causing a permenant strain of 0.002.

P: Yeild Point; the strain devio   from being propotional.

Y.S: is a measure of resistance to plastic deformation.

ـٰ ـٰ ـٰ   ﺗﻘﺎﺑﻞ A ﺍﻟ : true stress

strain

brittle

ductile

Ductility

Stress

Ductility: is the measure of the deformation
as fraction.

Percent of elongation:

$$\% EL = \left(\frac{L_f - L_o}{L_o}\right) \times 100\%$$

Percent reduction in area:

$$\% RA = \left(\frac{A_o - A_f}{A_o}\right) \times 100\%$$

Toughness: The ability to absorb energy up to fraction

Ex: A 850-lb force is applied to 0.15 in diameters nickel wire
have Y.S of 45,000 Psi and tensile strength of 55,000 Psi
Determine.

① whether the wire will plastically deform?
② whether the wire will experience necking
                                    sic

                                    necking formed from
                                    ductility

(a) $\frac{F}{A} = 6 = 48,100$ Psi $> 45,000$ Psi
the wire will plastically deform.

(b) $48,100 < 55,000$
No necking will occur

Ex: A 3-in diameter rod of copper is to be reduced to a 2-in diameter rod by being pushed through an opening to account for elastic strain, what should be the diameter of the opening.

$E = 17 \times 10^6$ psi

$Y.S = 40,000$ psi

$E = \sigma / \varepsilon = 0.00235$ Hook's law

$\varepsilon = \dfrac{(2-d_0)}{d_0} = 0.00235$

$\Rightarrow d_0 = 1.995$ in

Ex: A steel cable 1.25 in diameter and 50 ft long is to lift 20 ton load what is the length of the cable during lifting.

$E = 30 \times 10^6$ psi

$\sigma = F/A = 32,595$ Psi   ← الجهد لازم صح

$\varepsilon = \sigma/E = 0.0010865$ in

$\varepsilon = (L_f - 50) / 50 \, ft \Rightarrow L_f = 50.0543 \, ft$

Ex: The following data were collected from a standard 0.505 diameter test specimen of copper alloy (initial length $L_0 = 2$ in) after fracture the gage length is 3.014 in and the diameter is 0.374 in. Plot the data.

Toughness: Ability of material to absorb energy

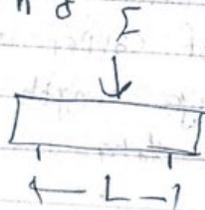| Load(in)	Gage length (in)	Stress (psi)	Strain
0	2	0	0
3,000	2.00167	15,000	0.000825
6,000	2.00333	30,000	0.001666
7,500	2.00417	37,500	0.002085
9,000	2.009	45,000	0.0045
10,500	2.04	52,500	0.02
12,000	2.26	60,000	0.13
12,400	2.5	60,000	0.25
11,400	3.02	57,000	0.51

ⓐ 0.2% offset % strength = 45 000 psi
ⓑ tensile strength = 62 000 psi
ⓒ $E = 18 \times 10^6$ psi
ⓓ % elongation = 50.7%
ⓔ % Reduction in area = 45.2%
ⓕ Eng. stress at fracture = 57,000 %
ⓖ true stress at fracture = 103,770 psi
ⓗ modulus of ~~resistance~~ resilience   ~~George Nasrala~~
$\frac{1}{2}$ (Y.strength) (strain at Yield) = 39.1 psi
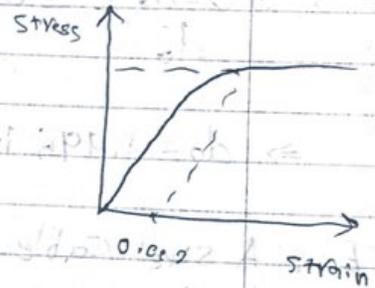
Flexural Strength $= \dfrac{3FL}{2wh^2}$ slide

Flexural.

Flexural modulus $= \dfrac{FL^3}{4wh^3 f}$

للتشية ـ:1 من التربية
Tensil Test
Bending Test
Hardness Test
الموصلية

Stress ↑

(graph with stress vs strain curve, 0.000 marked, strain axis)

Written by Essa Al-Sharif

*Fracture:

Fracture: Separation of a body into pieces due to stress at temp. below the melting point.

* Steps in fractures
① Crack formation.
② Crack Propagation.

قطعته

crack بداية الشظ

cracks بداية ما يبدأ الشظ

Two fracture modes:
① Ductile fracture - most metals (but not too cold)
  * ~~Extense~~ Extensive plastic deformation a head of crack
  * Crack "Stable" resists further extension unless applied stress
    is increased.   لازم يزيد الstress عشان يبدأ بالcrack

② Brittle fracture, ceramice, Cold material
  * little Plastic deformation.
  * Crack is "unstable"
    propagates rapidly without increase in applied stress.
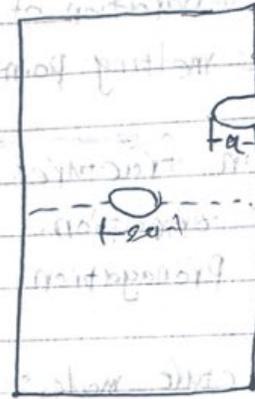
*Stress Concentration:
Fracture strength of a brittle solid is related to the Cohesive forces between atoms.
The theoretical cohesive strength of a brittle material should be $E/10$, but experimental fracture strength is normally $E/100 - E/10000$

* This much lower fracture strength is explained by the effect of stress concentration of microscopic flaws.
* The applied stress is amlified at the tips of microcracks, voids, notchs, surface, Scra

that are called stress raisers

max stress near the crack tip is

$$\sigma_m = 2\sigma_0 \left(\frac{a}{\rho_t}\right)^{\frac{1}{2}}$$

σ_0: is the applied stress.
a: is the half length of the crack
ρ_t: raduis of the curvature of the crack tip

$$K_t = \frac{\sigma_m}{\sigma_0} \simeq 2\left(\frac{a}{\rho_t}\right)^{\frac{1}{2}} \qquad \text{Stress Concentration factor}$$

Fatigue:
Under fluctuating/cyclic stresses failure can occur at load ~~condition~~ Considerable lower than tensile or yield strength of material under static load.

* 90% of all failures of metalic structures is due to fatigue.
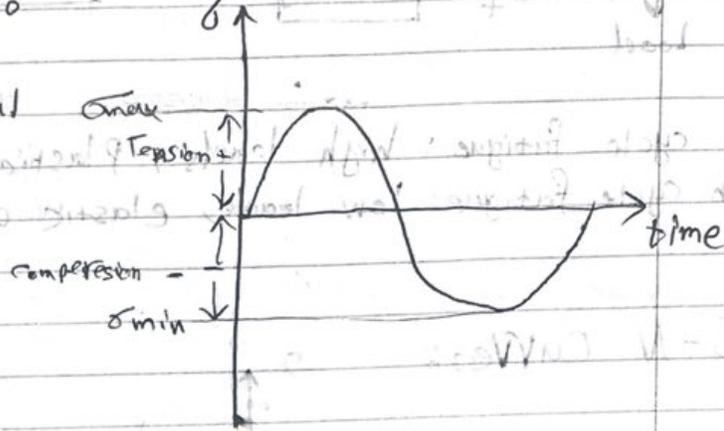* Fatigue failure is brittle-like stages of fatigue.

Dr George

~~③ Crack initation in the~~ ③ Catastrophic failure

② Incremental Crack Propagation

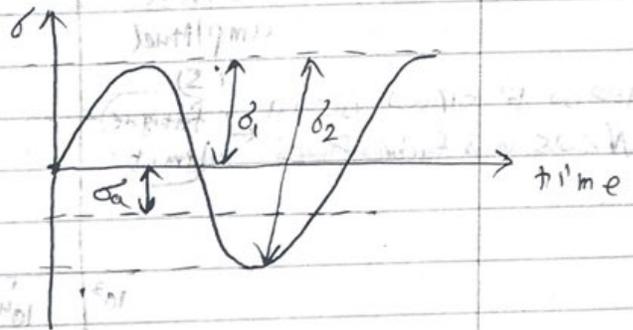① crack initation in the areas of stress Concentration

Fatigue cycle Stresses:

① Periodic and Symmetrical about Zero
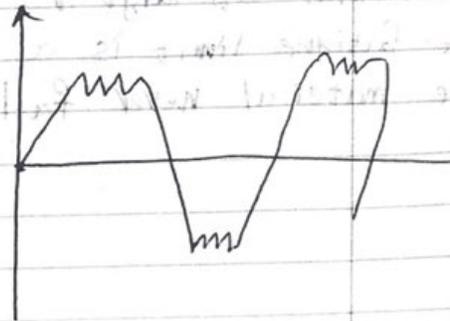

② Periodic and a Symmetrical about zero.
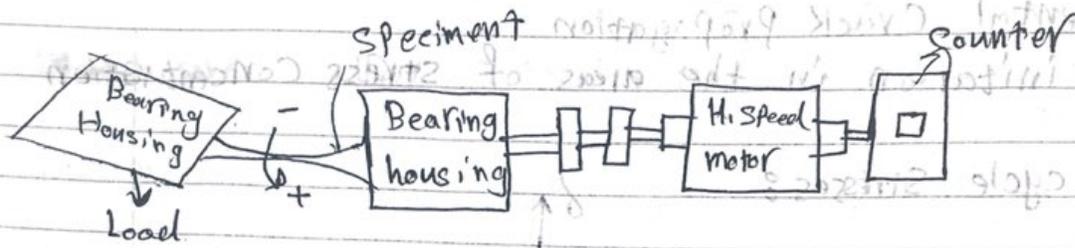
mean Stress $= \sigma_m = (\sigma_{max} + \sigma_{min})/2$

Rang of Stress $= \sigma_r = \sigma_{max} - \sigma_{min}$

Stress amplitude $= \sigma_a = \sigma_r/2 = (\sigma_{max} - \sigma_{min})/2$
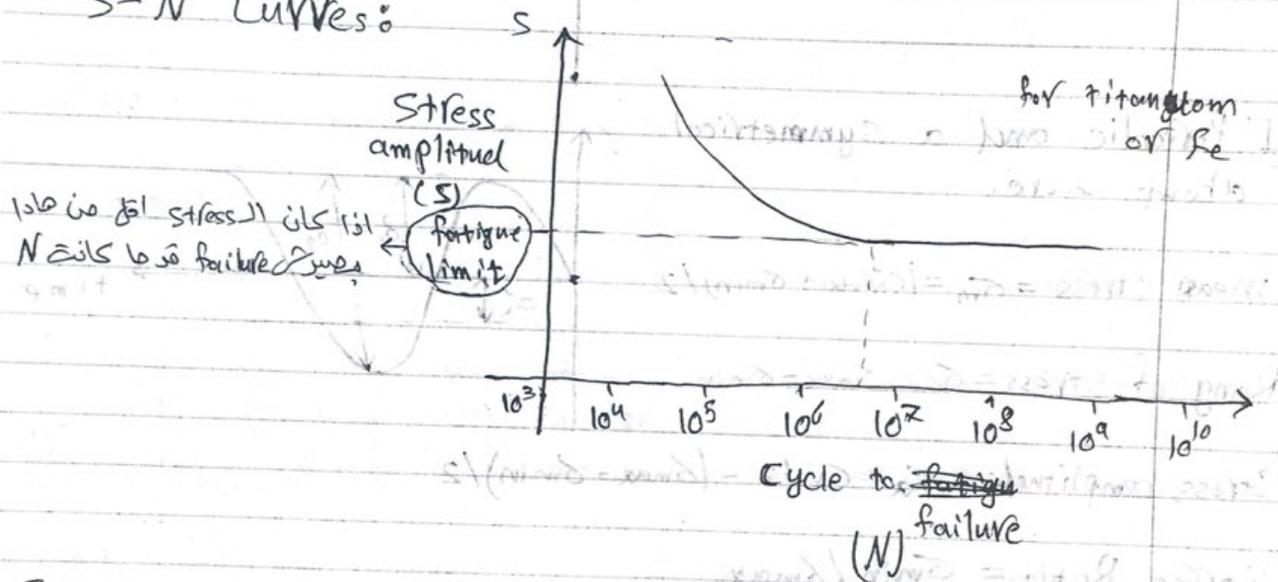
Stress Ratio $= \sigma_{min}/\sigma_{max}$

③ Random Stress

Low cycle fatigue : high loads , plastic and elastic deformation
High cycle fatigue: low loads, elastic deformation, $N > 10^5$

S-N Curves:

اذا كان ال stress اقل من هاي قيمة
بصير قيمة ال failure مالا نهاية $N = \infty$

Fatigue Limit (endurance limit) : in this case, S-N curve become
horizantal at large N.
the fatigue limit is a max stress amplitude below which
the material never fails, no matter how large N is.
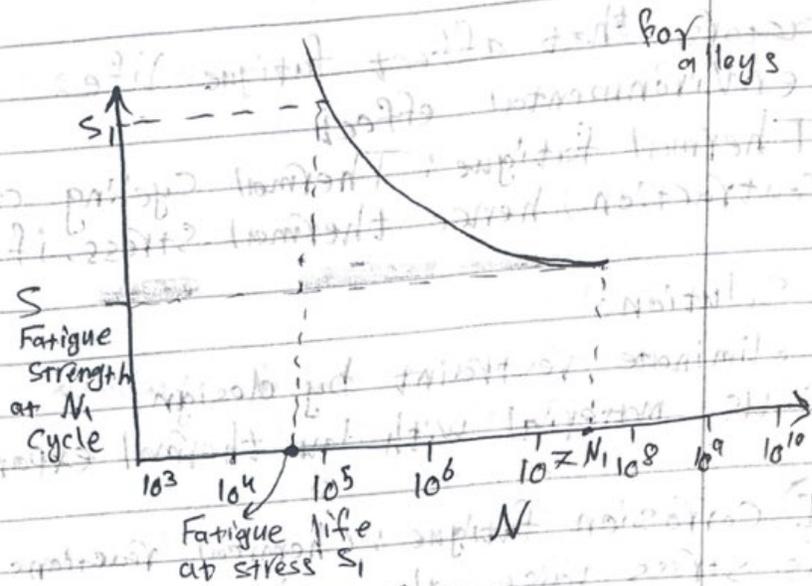
* Fatigue Strength: Stress at which fractur occur after specified number of cycles ($\approx 10^7$) يعني ثابت

* Fatigue life: Number of cycles to fail at ~~stress~~ specified stress level.

Factors that affect fatigue life:
① magnitude of stress
② quality of surface (scratches, edgs, sharp transition ...)

Solution to increase life of fatigue:
① (Removes machining flow) Polishing.
② Shot peening   الكبير
③ Case hardling (heat treatment
④ optimizing geometrey: avoid internal corners

*Factors that affect fatigue life:
- environmental effect

*Thermal fatigue: Thermal cycling causes expansion &
contraction, hence thermal stress, if component is restrained

Solution:
① eliminate restraint by design
② use material with low thermal expansion coeff.

(II) corrosion fatigue: Chemical reactions induce pits which act
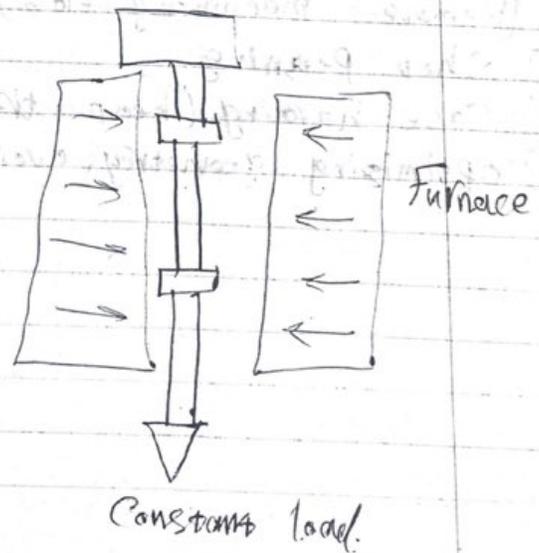as stress raises also enhance crack propagation.

Solution:
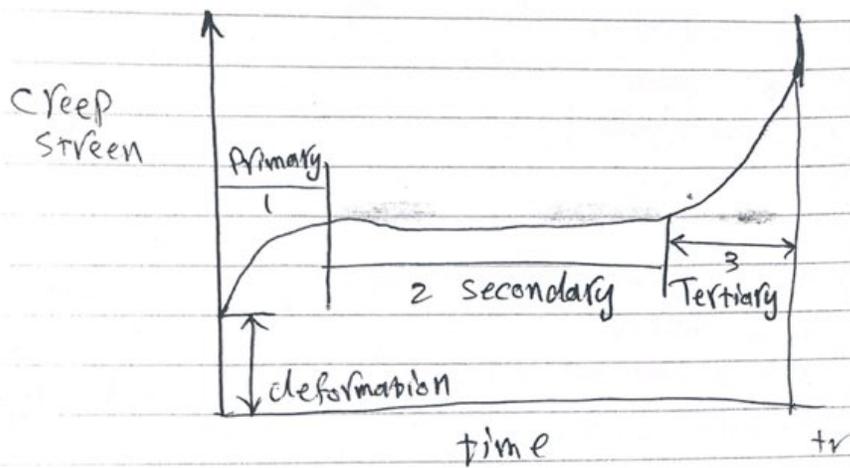① add protection surface coating.
② decrease corrosiveness medium.

& Creep:
Creep is the time dependent and permenent deformation of
materials when subjected to a constant load at a high
Tempreture (> 0.4 Tm)

Examples: turbine blades, steam generators.

Furnace

Constant load.

صلابة Hardness

① Instantaneous deformation
② Primary / transeat creep
③ secondary / steady-state creep: Rate of straining is
④ Tertiary: Rapidly acceleration strain rate up to failure