National institute of Technology

(Hamirpur)

Updated On:- 01/03/2021

Subject:- Surface Engineering

Course-code:- MSD-325

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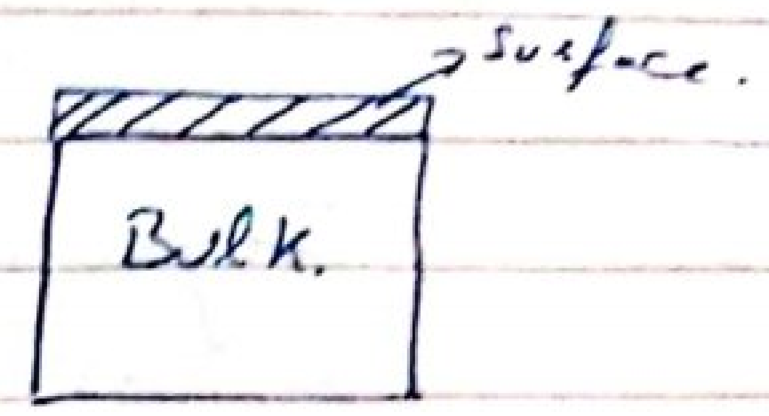
Surface Engineering targets 2 aspects:



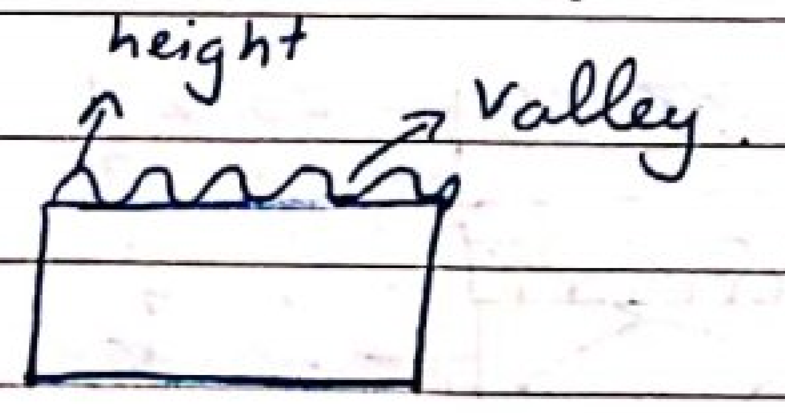
1) Improve surface characteristics
2) Enhance the surface properties.

Surface comprises ① Features present at the surface
② Sub-surface features

① SURFACE FEATURE

→ Mechanical components made by diff. manufacturing process eg cutting, casting, welding, machining, etc.

→ By this A lot of irregularities appear on the surface which is quantified as Surface Roughness.



→ Surface roughness is characterized by:
a) stylus based method (by touching) we get avg. roughness value Ra.
b) Non-contact (AFM)

Machining – 0.2 – 4 μm. → surface roughness
↓
0.1 – 1 μm → after polishing (finishing).
Ra

→ Finishing is important as surface finish affect friction and wear behaviour of the component.

↑very high

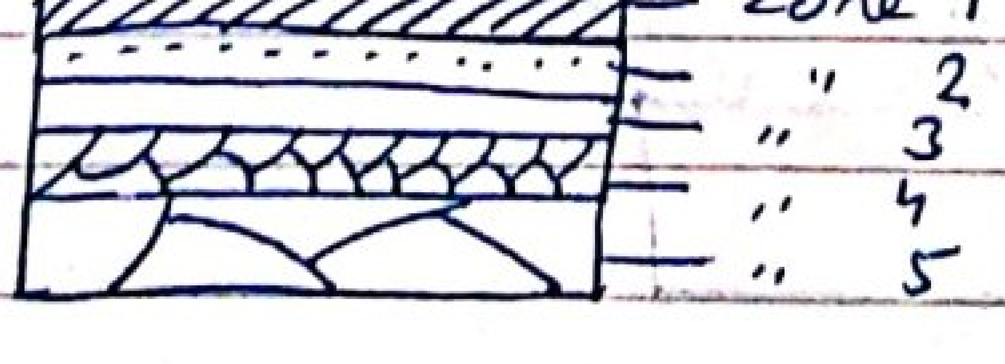
Surface Roughness → Higher friction

↓very low.

↓ if Optimum level of Ra.

good wear & friction Resistance.

② Sub Surfaces



a) **Zone 1** (Contamination layer)

approx few nm thin contamination layer

↓ why

As it absorb gases eg hydrocarbons, moisture, etc.

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b) Zone-2

Some atmospheric gases ($O_2/N_2/H_2$) interact with substrate surface then impurities such as oxides, Nitrides, etc. form.

Eg Iron oxide, Al_2O_3.

c) Zone - 3 (Damaged zone)

Material subjected to shaping and sizing process.

Causes Crystalline structure to damage as high strain and high plastic deformation occur.

→ Thin layer (< 1 µm thin).

d) Zone - 4

→ Thickness → 20 - 100 µm

→ This is Due to machined components

→ In this Grain structure is deformed. Orientation and shape of grain change due to strain and plastic deformation.

→ Higher hardness due to work hardening effect.

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e) Zone 5 (Unaffected Zone)

There is no effect of temp. or mechanical pores in this zone.

This is base material which is not damaged/changed.

⇒ Surface Engineering technique ~~[illegible]~~ will affect 1 or more of these zones (ie modified or altered)

⇒ Surface engineering or Modification approach:

① Heat is applied
② Forces are being applied.

① ~~Hea~~ Application of heat
→ It remove the absorbed gases or moisture & hydrocarbons.

→ Thermal decomposition of oxide layer. (affect zone 1 & 2).

② Mechanical forces Application. (4th upto zone)
→ Large scale damage to these zones.
→ Significant work hardening is there which gives high hardness and improve mechanical properties of components.

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For a particular application we need to know what properties we require ~~some~~ after surface modification

Eg
good corossion resistance
" wear resistance
" Thermal properties

-> let we have a mechanical component and we require wear resistance.

-> for this we have to check tribological performance which affects the life of component under wear condition.

Tribology :- Greek word -> Tribos (Rubbing)
Science & engineering of interacting surface in relative motion including the study and application of the principle of friction, wear & lubrication.

Tribology performance of any component subjected to wear is governed by:
① Physical
② Mechanical
③ Chemical
④ Dimensional
Properties of the surface of engineering component.

(i) Physical Property: Melting point, resistance to softening, thermal expansion coefficient.

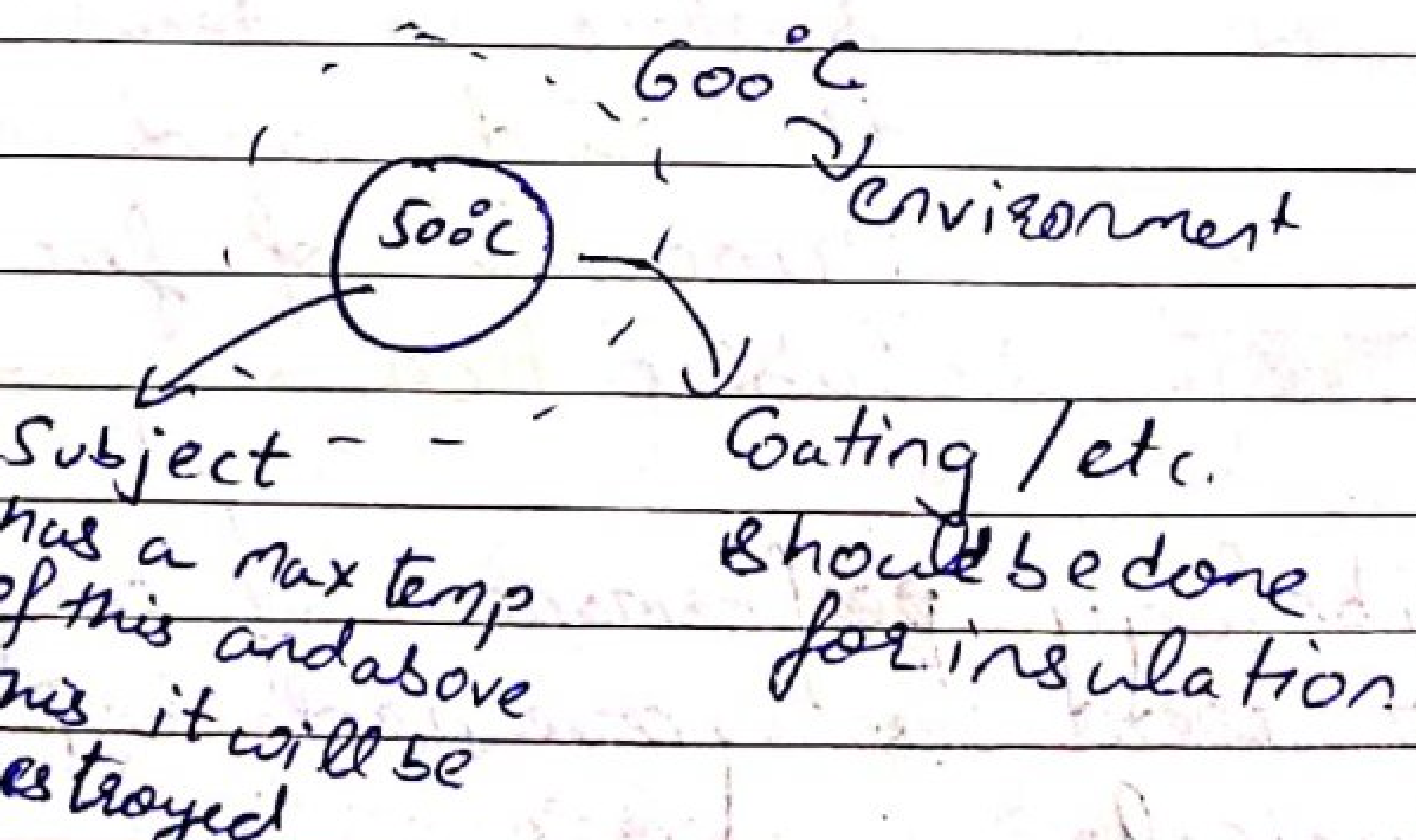
a) <u>Thermal conductivity</u>: How fast heat would transfer from 1 region to other region (where the heat generated due to friction.

Eg if K is high
then faster heat transfer from one region to other.

Metal $\epsilon \rightarrow K\uparrow$ ⇒ Able to retain its property

b) <u>Thermal insulation</u>: we need low K. ($K\downarrow$)

Eg

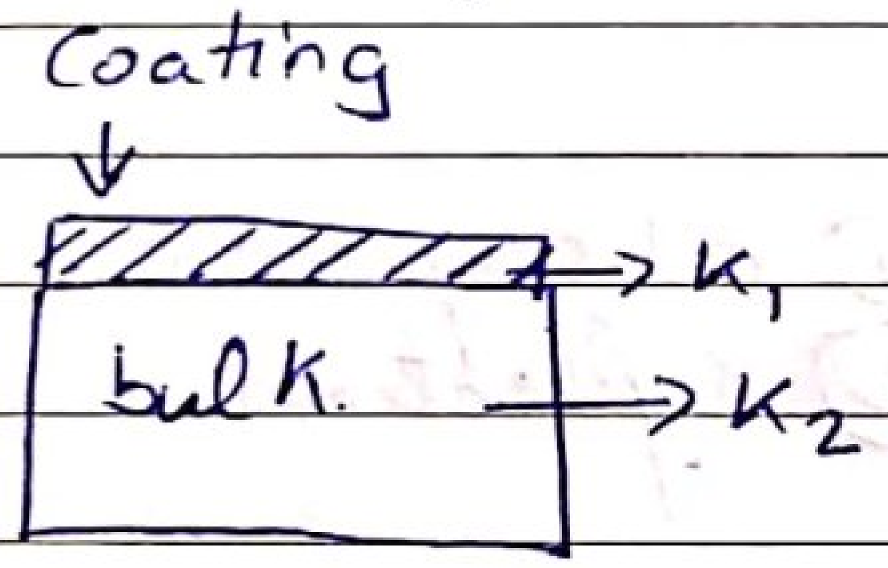


→ For high temp. application
→ Eg Turbine blade (~1600°C)
→ Thermal barrier coating.

$K\downarrow$ => want to preserve heat or protect component from high temp.

Eg Heat engines -> more heat should preserve (less heat loss).
∴ Coating is done on internal surface of cylinder.

c) Thermal expansion coefficient



① if $K_1 = K_2$
the coating will sustain the thermal cycle.

② $K_1 < K_2$ (less diff. i.e. $K_1 \approx 12$ units, $K_2 \approx 16$ units)

during Thermal cycle (heating & cooling), coating may peel off.

d) Refractoriness : High temp. resistance.

Cutting tools (WC, HSS) ⇒ Coating on these cutting tools to retain their hardness at high temp.

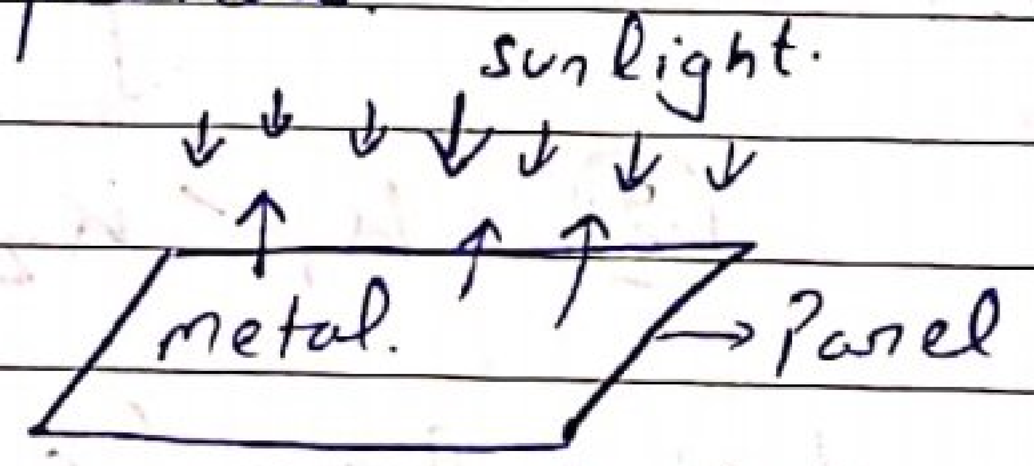
i.e. Hot hardness is required as temp gets high during cutting action which can soften the tool material.

So we require coating material with refractoriness
⇓
→ should not melt,
→ " not thermally soften,
→ " Retain hardness at high temp.

e) <u>Optical Properties</u> :

Used in both ways ① absorption
② reflection

Eg solar panels



some absorb
some reflect
∴ energy loss is there.

(i) coating: We can apply coating as surface modification so that sunlight which falls on panel can absorb fully and can be used as heat and used for various purposes.

(ii) Roughening :- inc absorption capacity.

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⇒ Steath Coating

Air force uses the aircrafts with the technologies where aircraft can not be seen with radars.

↳ they send radiation and based on reflections the object is recognised and its position, size, shape, etc can be identified.

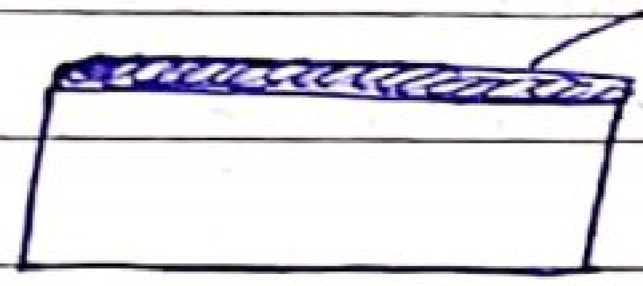
Nanopaints absorb the waves from radar ∴ helps in non detection of aircrafts.

The coating absorb the radiations and dissipate them as heat then scatters in the atmosphere.

② Chemical Properties

a) Composition
b) Chemical affinity
c) Corrosion
d) Oxidation

a) Composition



→ One or more kind of metal systems.

Chemical composition is importantas it affects microstructure which affect mechanical and corrosion properties.

Sometimes we need to know which kind of surface (compositional modification) modification is required for a metallurgical feature that provide required mechanical & tribological properties.

Based on this we give Surface/Compositional modification treatment eg carburizing, nitriding, etc. which will change near surface layer composition.

b) Chemical Affinity

All metals have some chemical affinity towards metals, non metals, gases.

Metal — surrounding gases

Interact to give a layer which is favourable or sometimes not.

Stainess steel	Fe	Al
Cr_2O_3	Rust	Al_2O_3

Interaction is desirable (Resistant to corrosion)

↓ desirable or not

characteristics of oxides, nitrides formation on surface

Cr, Al ⇒ oxide ⇒ Coherent and adherent non porous

⇓

good corrosion resistant

Fe oxide ⇒ porous, non adherent
non coherent
↓
easily peel off or removed

Continuous formation & removal of oxide will result in fast rate of material loss from surface.

c) Corrosion and Oxidation

→ These both affect surface properties

→ It is surface respond to surroundings

oxidation

Eg some metal has good resistance to oxidation even at high temp.
Ni, Cr or Co based systems are like this.
∴ used for high temp. applications.

Corrosion

Eg some metal like austenitic stainless steel has good corrosion resistance.

→ All metals don't interact in the same way to surroundings.

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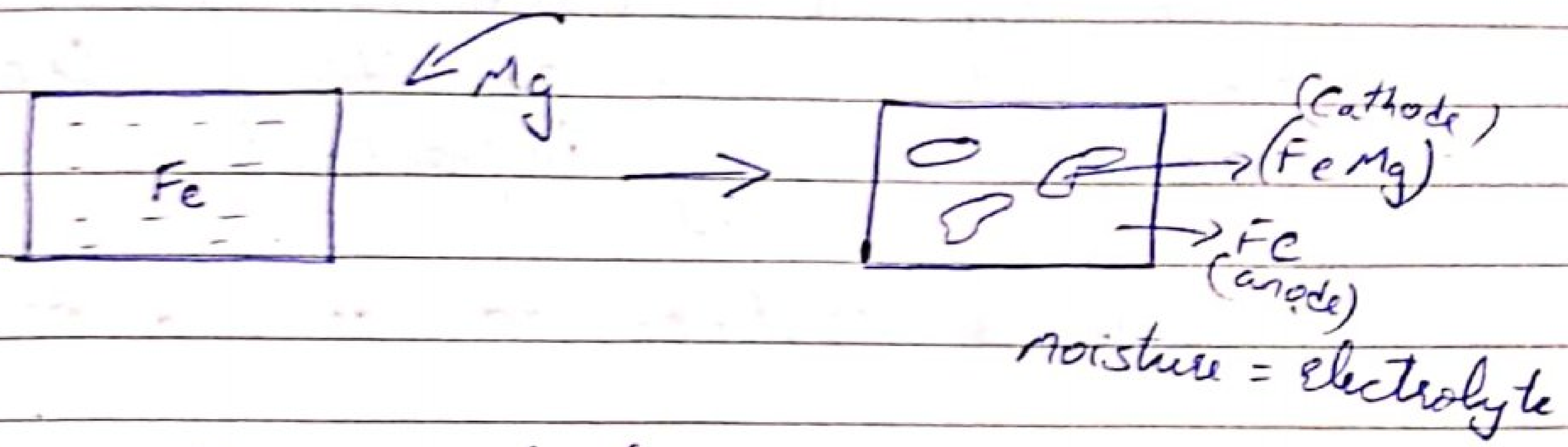
→ Chemical composition homogeneity is also very important

Eg.



✓ Pure Fe will corrode slowly
✓ But when it is alloyed or impurity is there then, the corrosion is very fast as Electrolytic cell is formed.

∴ Oxidation & reduction speed up and corrosion occur at fast rate.

→ Absence of segregation or localised presence of some elements is there then we can improve corrosion resistance.

3. Mechanical Properties :-

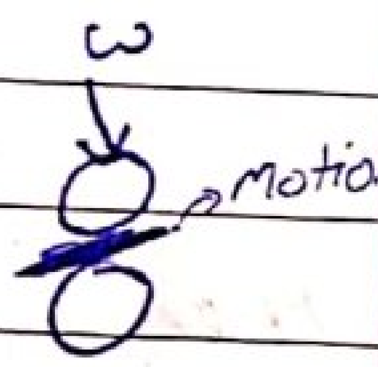
a) ~~Hardness~~

→ Under any wear condition (adhesive, abrasive, erosive conditions) then the hardness is very important.

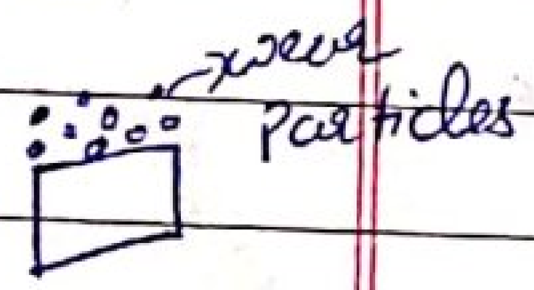
→ Hardness is resistance to indentation or abrasion.

→ Minimum stress needed to produce irreversible plastic deformation to the solid surface.

⇒ ↑Hardness ⇒ ↑ abrasion resistance
↑ adhesive resistance



Archard's Law : for adhesive wear case.



$$\boxed{V = \frac{K \omega L}{H}}$$

V = wear volume → got from profilometer
K = dimensionless const.
ω = Total normal load
L = sliding dist. → amplitude of ~~sliding~~.
H = Hardness of the softest contacting surface.

$$\therefore \boxed{V \propto \frac{1}{H}}$$

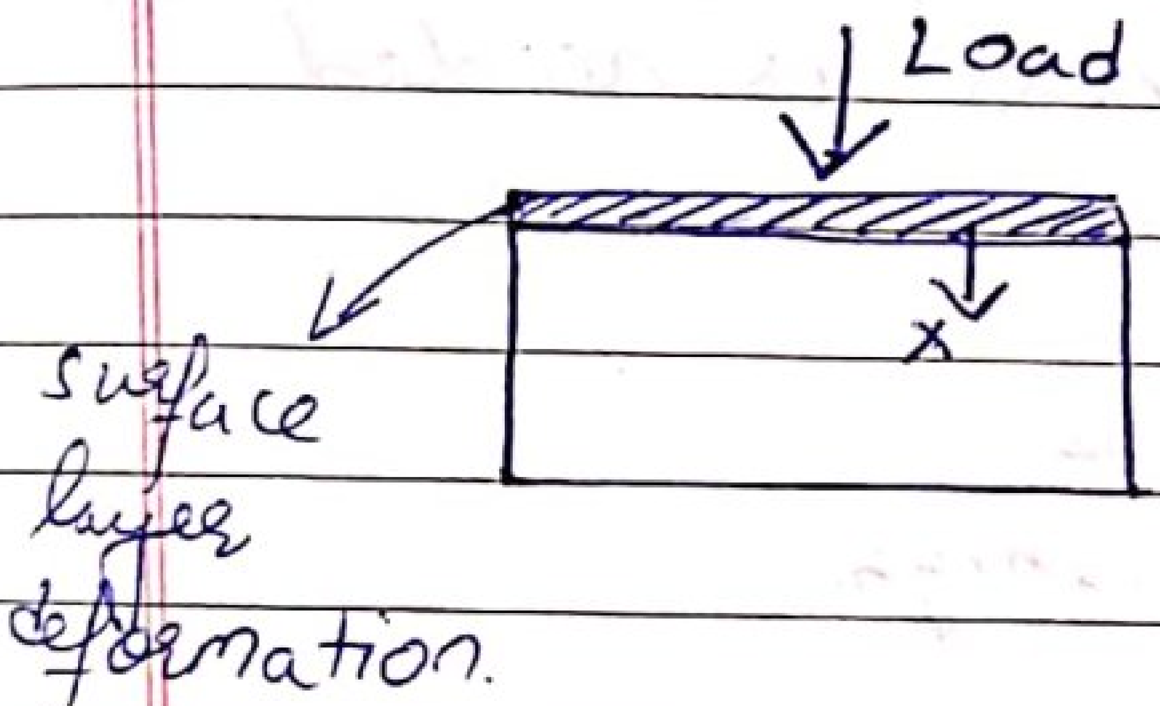
Hardness b/w 2 materials should be diff. considerable for this.

b) Strength

when it is supposed to take the load

Modification → coating / diffusion of alloying element → Surface should be strong enough

Coating



transfer of load from coating to material should not be there.

c) Ductility

when Heavy loads are applied, then ductility is important.

As ductility resist the nucleation and growth of the crack

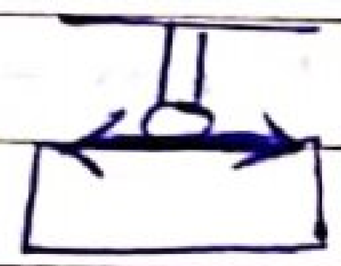
Surface fatigue condition → need good strength and ductility.

d) Fracture toughness

→ It is important for resistance of crack growth.

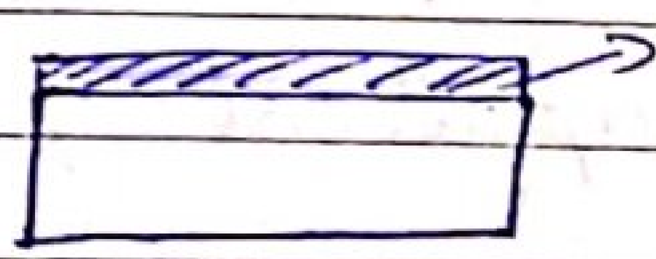
→ Needed where Surface fatigue is there or fretting wear is there, where there is chance of crack development and subsequent growth. which lead to removal of material from surface.

→ ∴ we need ~~surface~~ strength, ductility and fracture toughness is needed.



Load is less
frequency is high.

e) Bond strength

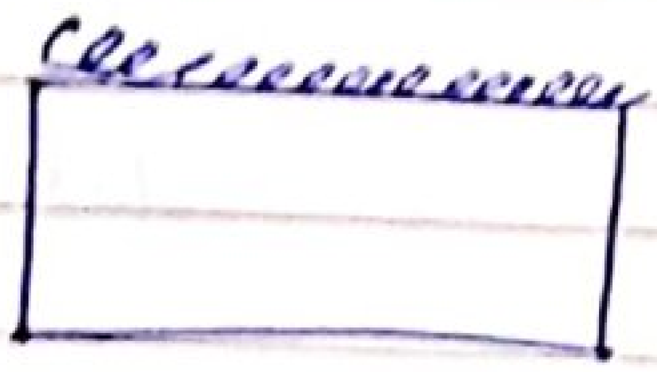


coating

→ bond of coating with base material is very important.

→ Coating adhesion strength should be > 70 MPa otherwise peeling off or spalling of coating will be ↑.

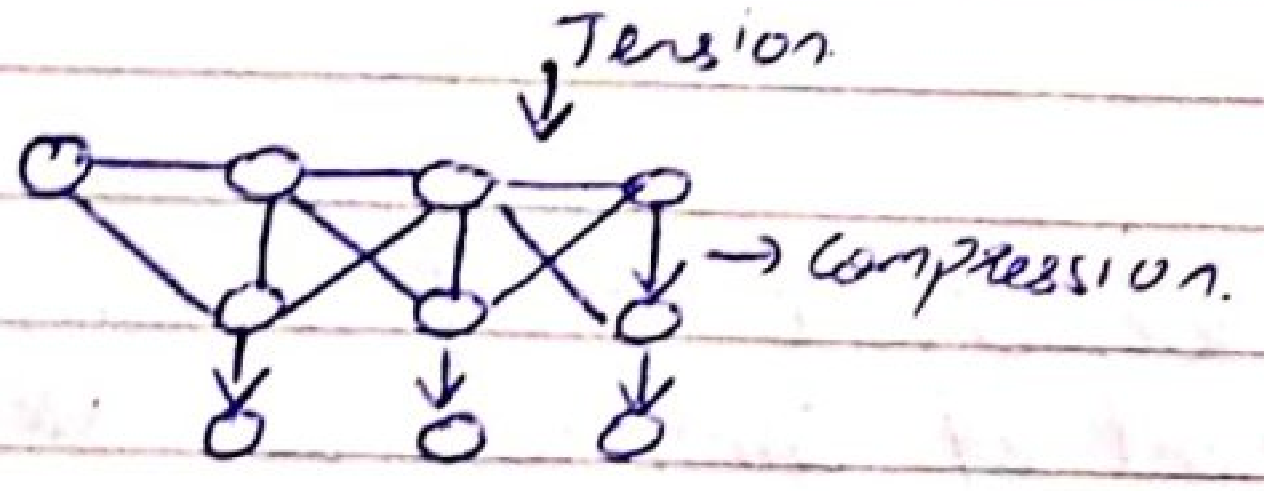
f) Residual stress



Material surface is heated then cooled
ex thermal fatigue.

→ ∴ There will be development of tensile residual stresses on surface

→ Sub surface region will be in compression.



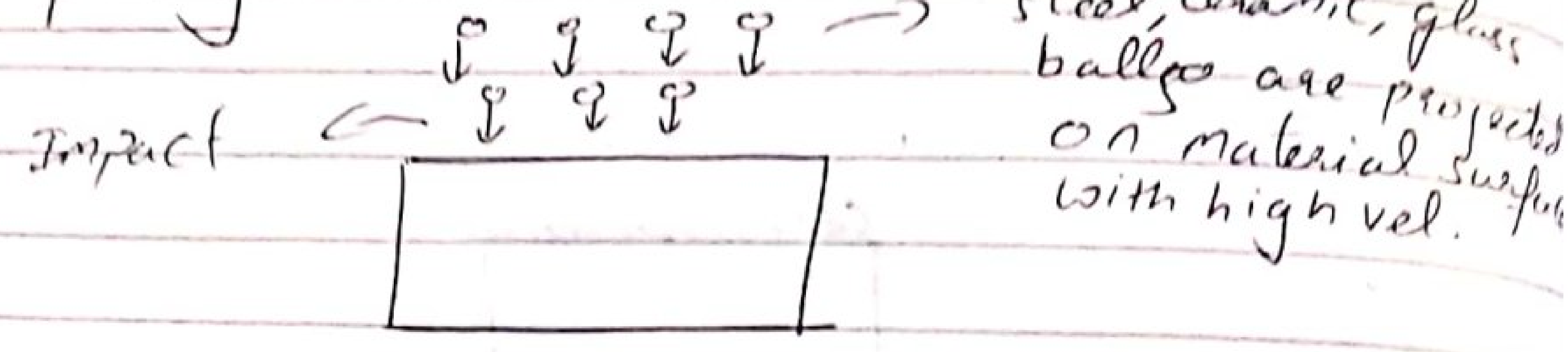
∴ Tensile residual stress will result in crack nucleation & growth.

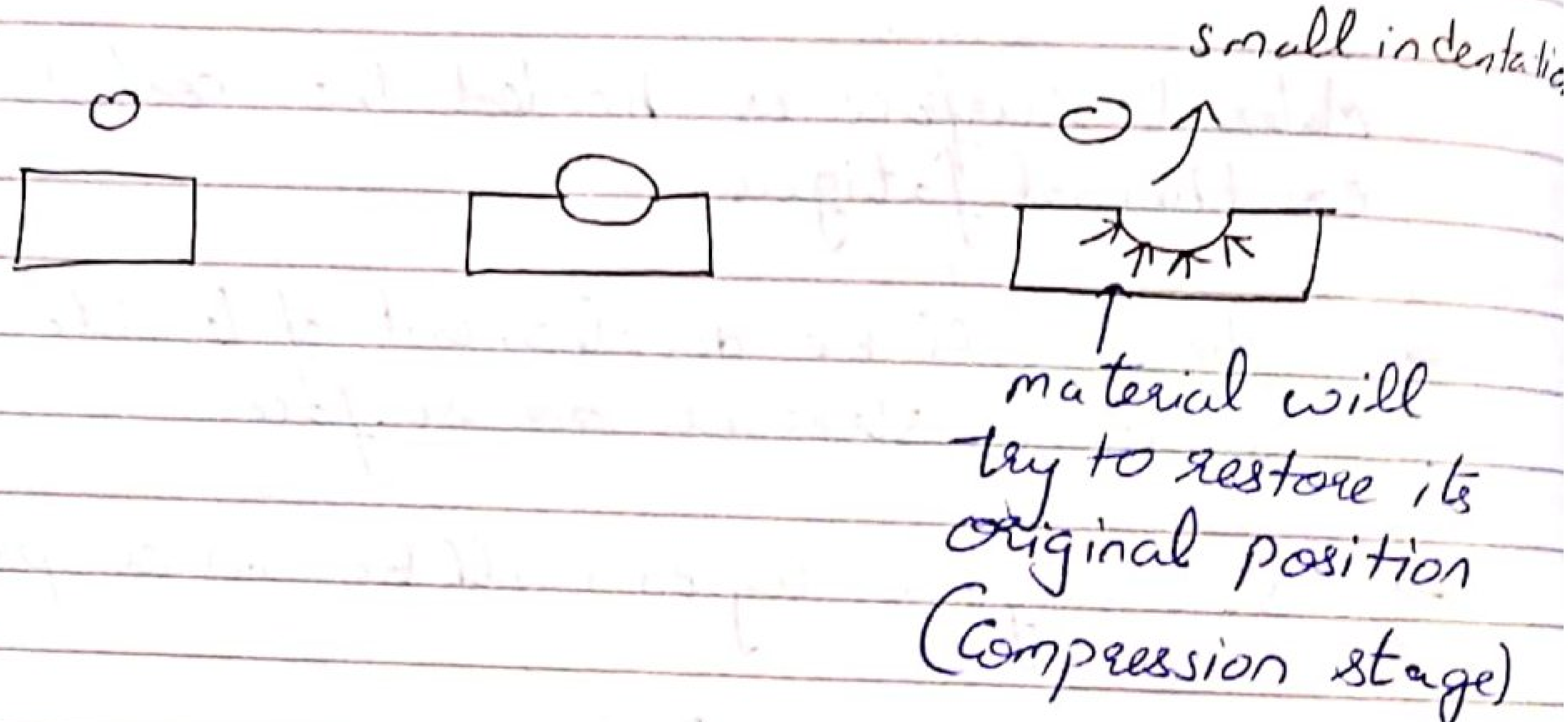
If Tensile stresses are higher than tensile strength of material, crack will ~~grow~~ form

Surface modification should be done in order to have compressive stresses at the surface.

For this short peening on the surface is done.

Shot peeing





∴

Because of localised surface layer deformation & development of compressive residual stresses

→ fatigue resistance ↑

→ Wear resistance ↑

∴ Shot peeing is done to inc. resistance.

g) Stress Corrosion Cracking

Loading under corrosive condition

- → If metal is sensitive to corrosion,
- → corrosion medium
- → tensile stress

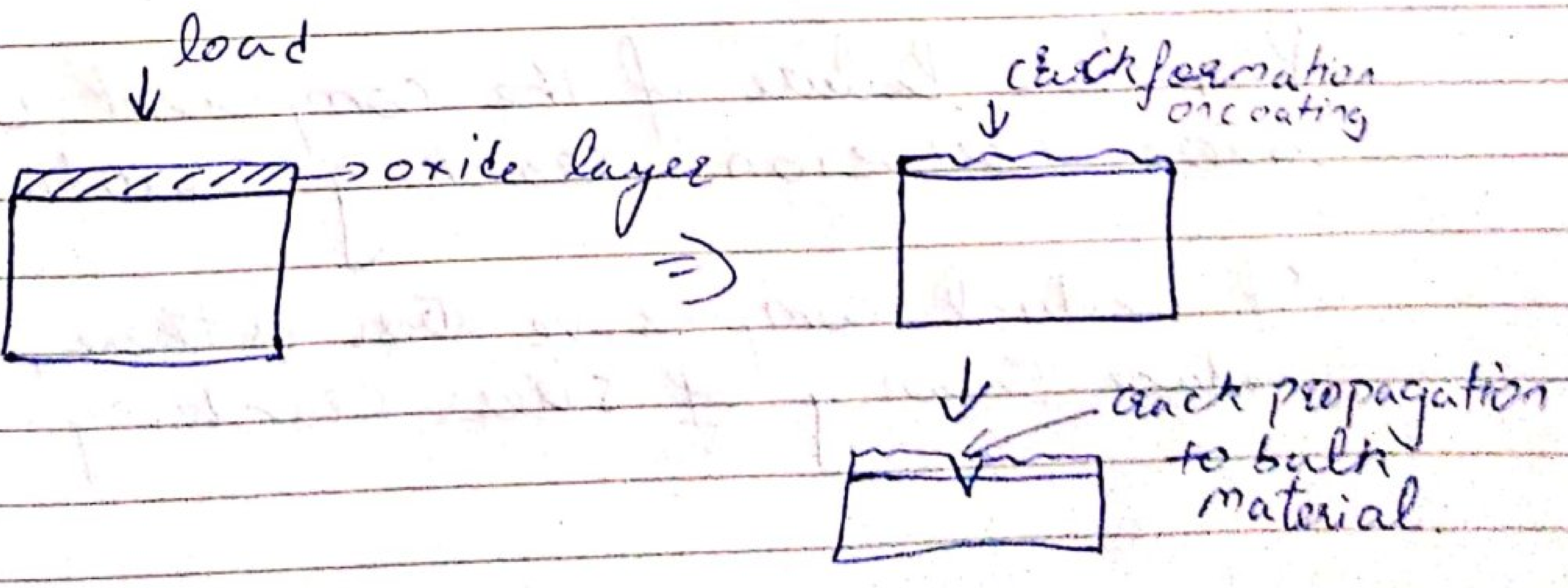
] All These 3 Parameters should be present for stress corrosion cracking

∴ faster growth of crack is there

Nucleation of crack at high stress conc. area ∴ faster growth

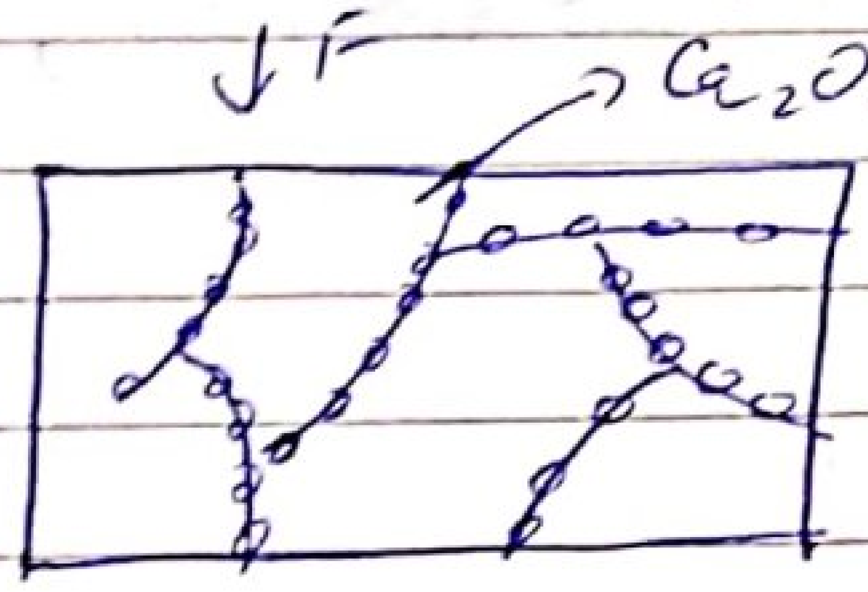
Susceptible metal	Specific corrosive environment
Cu alloy	NH_3
Mild steel	Alkalis and nitrates
stainless steel	Chlorides & acid Chlorides

(i)



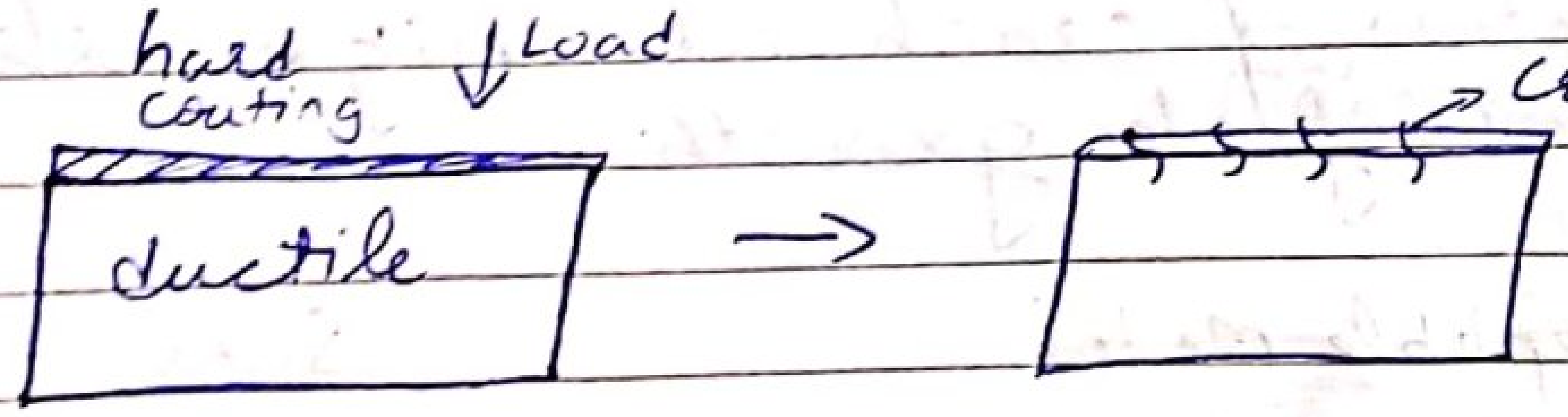
→ Crack propagation will take place when the rupture of oxide film is faster than the reformation (repassivation) of the film.

(ii)



Breaks the oxide film and electrolyte will diffuse from g.b. ~~→ corrosion film~~
→ corrosion rate ↑.

(iii)



& then propagate ~~as all liq. will~~ penetrate & corrode material also.

This is Brittle failure.

Premature failure of the component under stress corrosion cracking condition.

If Residual compressive stress is there, it will reduce tendency of stress cracking.

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(4) DIMENSIONAL PROPERTIES

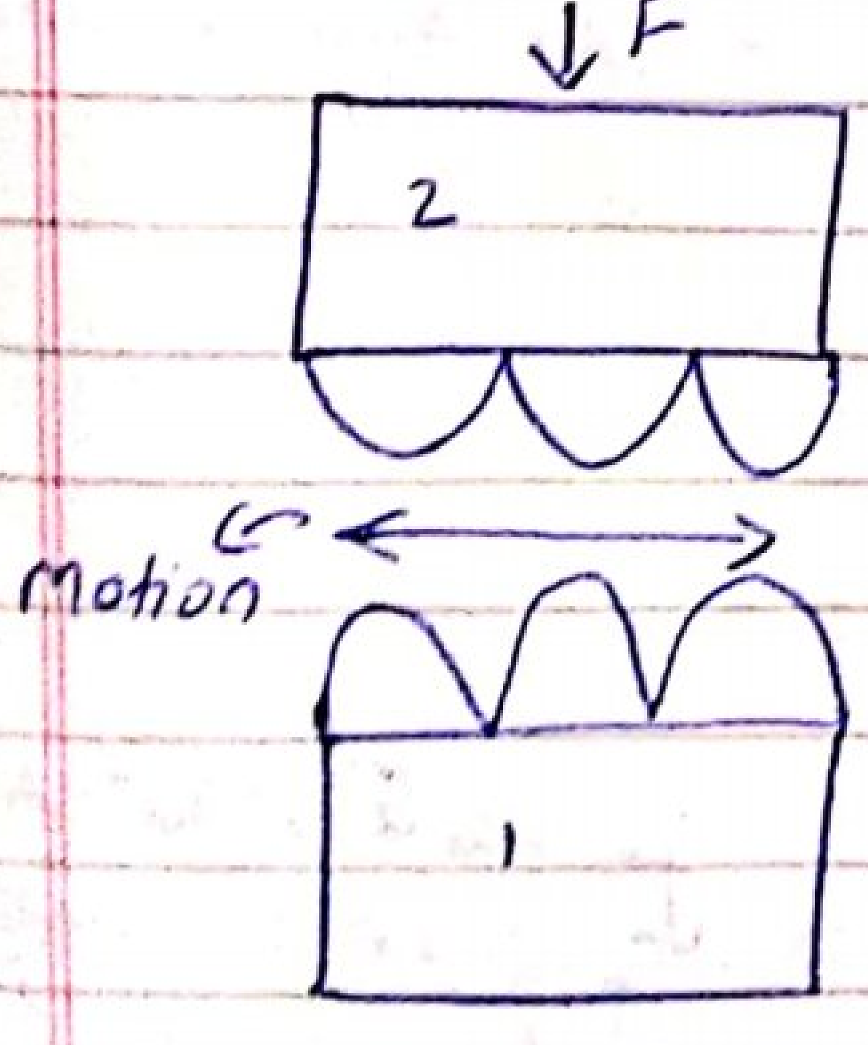
→ straightness
→ flatness
→ Roundness
→ Roughness

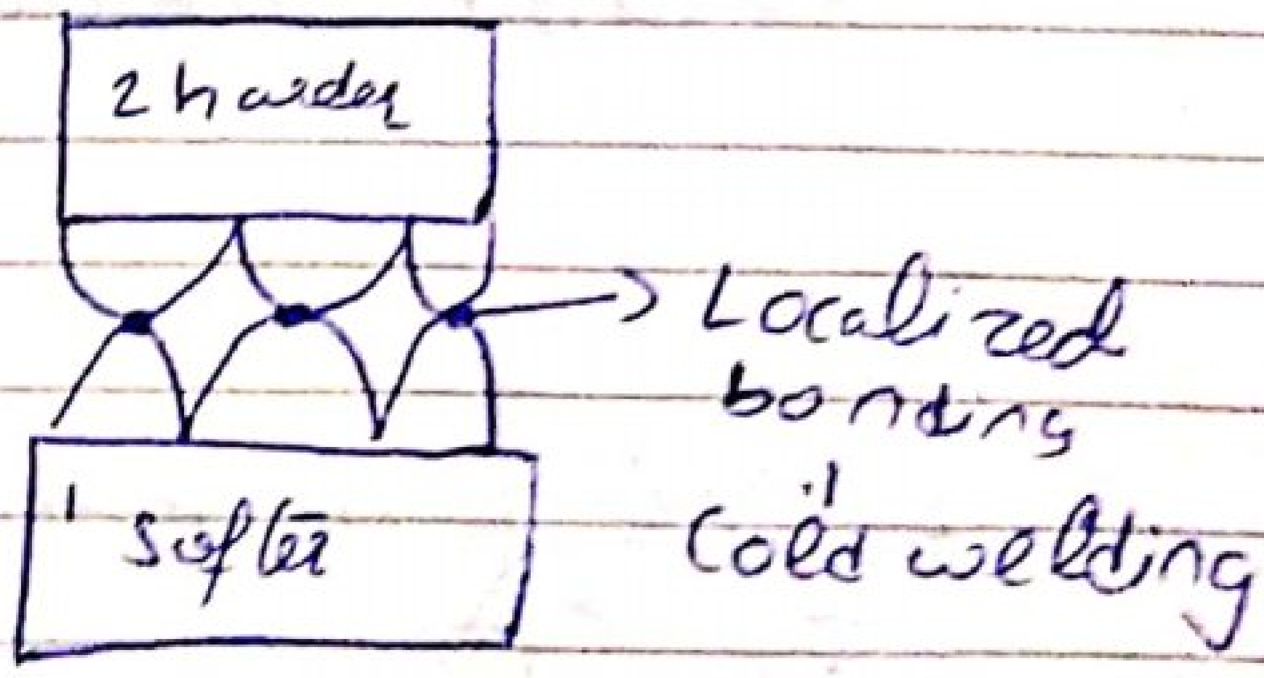
straightness and flat → smooth movement of components during service

Roughness

If it is ↑ , then wear rate ↑

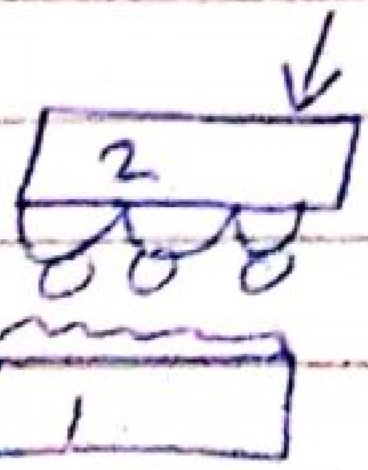
Adhesive condition





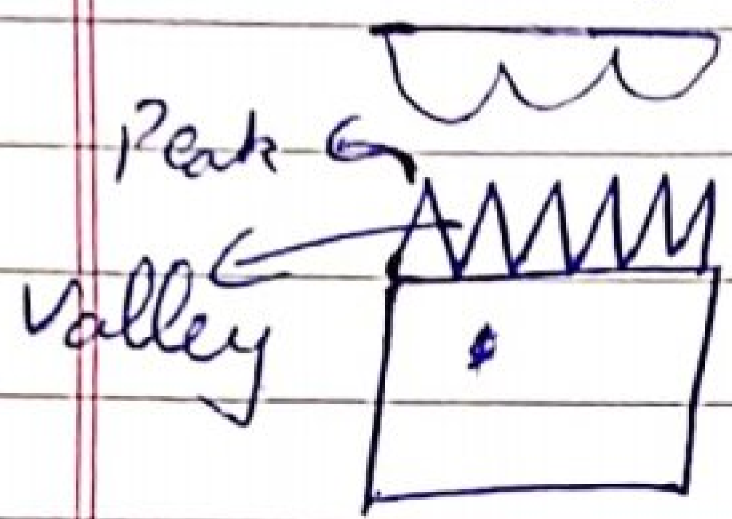
↓

Still this is in motion



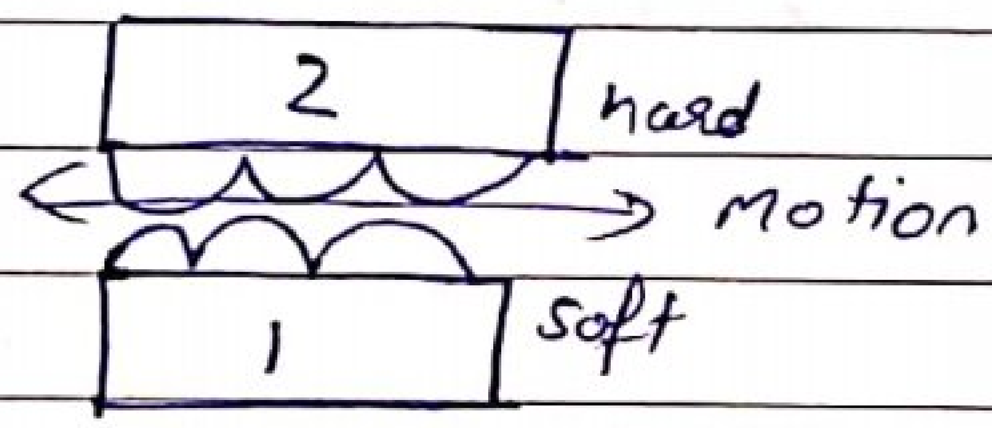
∴ 1st material will get removed and weld with 2.

If Roughness is very high

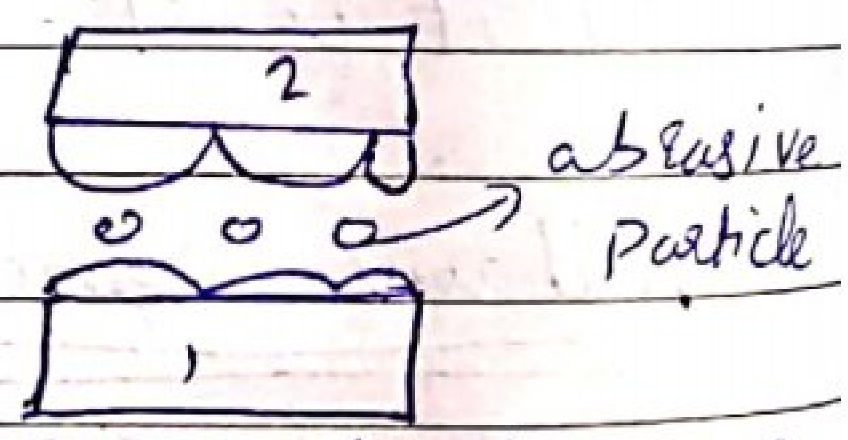


then peak & valley bonds (with material) under relative motion
↓
This removes a lot of material from surface of the other mate[rial]

Abrasive wear



2 Body abrasive wear



3 body abrasive wear

∴ abrasion will occur

Peaks will indent soft metal under relative motion → generate scratch groove on surface and alot of material will lose.

Lowstress abrasion
high stress abrasion
gouging abrasion
Polishing abrasion

⇓

depends or based on surface & subsurface damage

Mechanisms → Plowing
→ Microfatigue
→ Wedge
→ Cutting
→ Microcracking