Toppersnotes

Unleash the topper in you

IES/GATE

MECHANICAL ENGINEERING

VOLUME - 4

STRENGTH OF MATERIALS (SOM)

SIERRA INNOVATIONS

Index

SOM

SOM

SOM

som / mos / mom / sm :-

Texet book

⇒ Mechanics of material – Timosheno and GERE (CBS publication)

⇒ Mechanics of solid – Popov (PHI publication)

⇒ Mechanics of material – Punamia and Ashok Kumar Jain (Laxmi publication)

⇒ Strength of Material – RAMAMRUTHAM (DHANPAT RAI PBLCN)

IES – PAPER-II

Objective – 65 to 70 marks.

conventional – 65 to 70

Topic of ENGINE MECHANICS

- F.B.D.
- Resolution of force
- Static equation cond^{ns}
- Centroid calculation
- Moment of Inertia
- Types of Support
- Support Reaction calculation

Chapter :- 1 Mechanics Of Material

MECHANICS

- ENGG. Mechanics (mechanics of rigid body)
  - Static
  - Dynamics
    - Kinematics
    - Kinetics
- SOM/MOM/MOS/SM (Mechanics of deformable body)
- Mechanics of fluid
  - mechanics of compressed fluid
  - Mechanics of incompressed flui

Mechanics is the branch of science which deals with the study of forces (both external and internal forces) and their effect on the structure, machine, fluids,

Machine :- It is combination of mechanism and mechanism is the combination of m/c element. It may be following type:-

1. Generating m/c
2. Converting m/c
3. Utilising m/c

Generating Machine :

Input: Some form of Energy → m/c → Output: mechanical Energy

Converting Machine :

mechanical Energy → m/c → Some form of energy

Utilising Machine :-

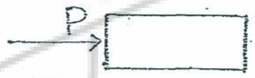
Recieve the energy from the generating machine and utilise the same during their functionality haft → bearing → key → Gear → pulley → belt → fasteners etc. will be design element if there is only shaft)

When the Relative position of particle remains same by applying external force then body said to be displaced body (only displacement occurs)

When Relative position of particle changes by applying external force then body said to be deformed body or (deformation takes place)

Engine Mechanics :- Study of external force and their effect on rigid body.

Strength of Material :- It is study of internal resisting force developed due to elastic deformation of a body under the action of a load.

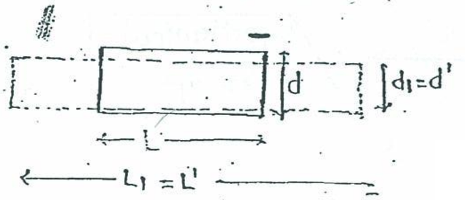


displacement

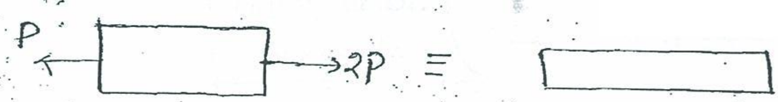
deformation
(SOM deals with this condn ie. body under equilibrium)

deformation and displacement (both occures)

said to be displaced and called rigid body



body said to be deformed body.



deformed + displaced.

All the component is assumed to under static Equilibrium.

The aim of som subject is to derive the expression for the stresses, deformation, strain which are developed under different loading condition by using experimentally obtained elastic propert like yong modulus.

Design:- Ultimate aim of the design is to develope a drawing (ie. selection of an appropiate shape, selection of appropiat material calculation of dimension by using som equation, selection of manufacturing process details, like surface finish, tolerance, limi and fits) in such a way that the resulting machine componet should perform its given functionality satisfactorily without any failure.

(design :- develop a trial)

(fracture :- break in two component
failure :- when fuctionality do not fulfill.)

Basic Requirement of M/c Element :-

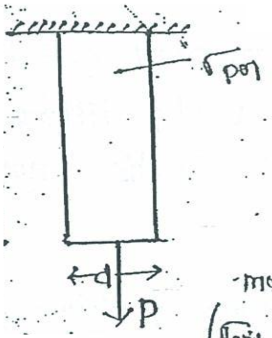
1. High strength
2. High Rigidity
3. Cost should be less
4. High service life
5. less weight

Design Criterian :-

1. Strength criterian ⟶ based on permissible stress
   ⇓
   not a property.
   obtained by taking safety of factor.
   Why use:- To find out the dimension of member

   (a) Allowable (b) Working (c) Safe (d) design stress

2. Rigidity ⟶ based on permissible deformation
   ↳ (obtained from standered codes)



Condition for safe design wrt strength Criterion

max. stress induced ≤ permissible stress

max. strength obtained by using som eq^n $\left(\sigma_{axial} = \frac{P}{A},\ \sigma_b = \frac{M}{Z},\ \tau_s = \frac{T}{Z_p}\right)$

permissible stress ↓ (obtained by taking factor of safety)

$$\frac{P}{A} \leq \frac{\text{failure stress}}{\text{F.O.S.}} \text{ or } \sigma_{per}$$

$$\frac{4P}{\pi d^2} \leq \frac{\text{failure stress}}{N} \text{ or } \frac{S_{yt}}{N}$$

S = strength
Y = yield
t = tension

$$\boxed{d \geq \sqrt{\frac{4PN}{\pi S_{yt}}}}$$

$\Rightarrow d \propto \sqrt{N}$

$d \geq 45.2\text{mm}$ (assume) then means

Condition for safe design wrt Rigidity Criterion:

max. deformation induced ≤ Permissible deformation

$\left(\delta_{axial} = \frac{PL}{AE},\ \theta = \frac{TL}{GJ},\ y = \frac{WL^3}{3EI},\ \frac{WL^3}{48EI}\right)$

$$\frac{PL}{AE} \leq \delta_{per}$$

$$\boxed{d \geq \sqrt{\frac{4PL}{\pi E \delta_{per}}}}$$

$d \geq 52.1$ mm (assume) then means

Assumption made in strength of Material Eqn.:

- Material is assumed to be both homogeneous and isotropic.
- Material obeys the hook's law
- Component is assumed to be prismatic.
- Load is assumed As static load.
- Effect of self weight is neglected.

Static load :- When mag. and dirn const wrt. time.

Prismatic :- All dimension are const or same throughout the structu

Homogeneous :- A material is said to be homogeneous when it exhi same elastic property at any pt in a given direc (ie. elastic property are independent of pt)

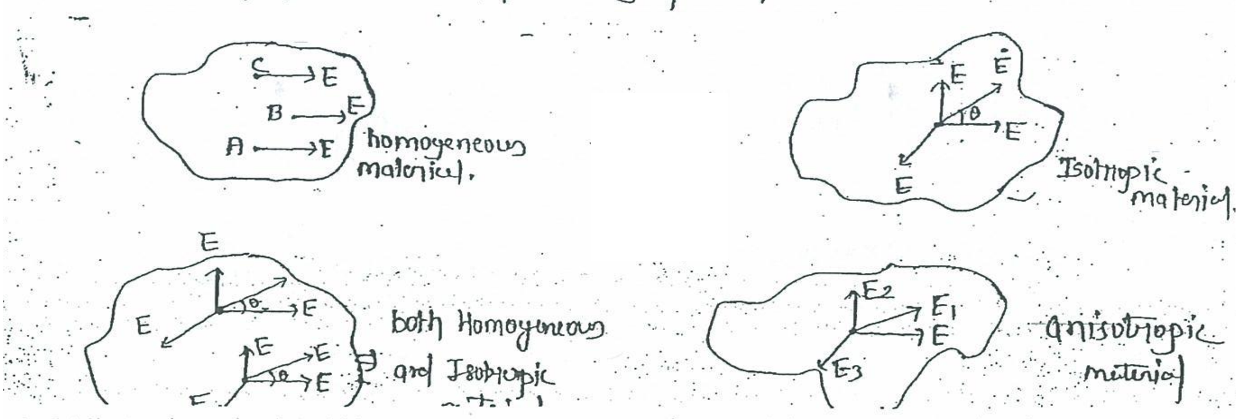
Isotropic :- A material is said to be isotropic when it exhibits same elastic properties in any direction at a given point. (ie. elastic property are independent of direction)

⇒ A material is said to be both homogeneous and isotropic when it exhibits same elastic property at any point in any di

⇒ Every homogeneous material need not be isotropic and vice versa but few material are both homogeneous and isotropic

⇒ A material is said to be anisotropic when it exhibits dirn dependent property of a point.

⇒ A material is said to be orthotropic when it exhibits diff. elastic property in orthogonal direction of a given point. exq:- Any layered material like plywood.



Toppersnotes
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Factor of Safety :- Factor of safety is used to determine the permissible stress or allowable stress or safe stress, working stress.

Permissible stress is used in design based on strength criterion.

$$(FOS) \quad N = \frac{\text{failure stress}}{\text{permissible stress}}$$

$$\text{Per. stress} = \frac{\text{failure stress}}{N}$$

failure strength = Yield strength —under→ Ductile material } Static load

= Ultimate strength —under→ Brittle material, also Ductile material

= Endurance limit } fatigue load

Brittle :- They will not permit any deformation and goes fracture.

Ductile :- Yield strength → when not undergo permanent deformation or under elastic limit

Ultimate strength → when undergoing permanent deformation

→ For a Given Material :-

$$\text{Per. stress} \propto \frac{1}{N}$$

when $N \uparrow \longrightarrow \sigma_{per} \downarrow \longrightarrow A \uparrow$ or dimension $\uparrow \longrightarrow$ safety $\uparrow \longrightarrow$ cost $\uparrow$

$\left(\sigma_{per} = \frac{P}{A}\right)$

$N \downarrow \longrightarrow \sigma_{per} \uparrow \longrightarrow A \downarrow$ or dimension $\downarrow \longrightarrow$ safety $\downarrow \longrightarrow$ cost $\downarrow$

Note :- In case of pressure vessel FOS is about 4.5 (minimum)

Marjine of safety (m):-

$$m = N-1$$

and if $N=1$

then $m=0$

$\Rightarrow$ failure design

and if $N>1$

$m>0$

$\Rightarrow$ safe design.

let $S_{yt} = 200\,mpa$.

(a) $N=2$

then $\sigma_{per} = \frac{200}{2} = 100$

and Reserve strength $= S_{yt} - \sigma_{PR} = 200-100 = 100$

(b) $N=4$

then $\sigma_{PR} = \frac{200}{4} = 50$

and Reserve strength $= S_{yt} - \sigma_{PR} = 200-50 = 150$

RESERVE STRENGTH :-

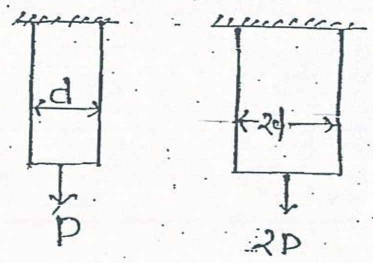
R.S. = failure stress − Permissible stress

) Factor of safety is incorporated in design of a m/c component to ensure some amount of reserve strength in component in case of in accident (ie. in presence of unknown loading cond, unknown environment cond^n, imperfect-workmanship, unreality of assumption made in some eq^n.

In presence of factor of safety the stress induced in component may exceed permissible stress but lies below the failure stress.

$$\sigma_{per} < \sigma_{ind} < \text{failure stress}$$

iv. What is the factor of safety when dia of an axially loaded member and axial load both doubles.



1st case:– $\sigma_{ind})_1 = \frac{P_1}{A_1} = \frac{P}{A}$

$\sigma_{ind})_2 = \frac{P_2}{A_2} = \frac{2P}{4A} = \frac{1}{2}\left[\frac{P}{A}\right]$

as material same hence failure stress is same

$\sigma_{ind} \leq \frac{\text{failure stress}}{N}$

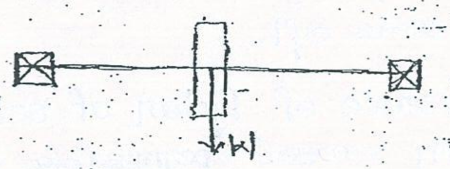
$\sigma_{ind} \propto \frac{1}{N}$

$\frac{\sigma_{ind})_1}{\sigma_{ind})_2} = \frac{N_2}{N_1}$

$2 = \frac{N_2}{N_1}$

$\boxed{N_2 = 2N_1}$

LOAD:– Load is defined as an external force or a couple to which a component is subjected during its functionality weight of a component wrt. another component. Centrifugal forces, inertia forces, gas load, belt tensions, twisting couple wind forces, bending couples etc.

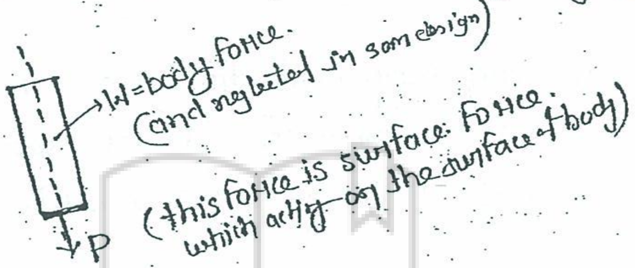


⇒ In the design of shaft
Weight of pully (W) is considered
Weight of shaft is neglected.

⇒ In design of bearing
Weight of pully and weight of shaft considered

Forces

- **Surface Force**
  - These are distributed over the area of surface.
  - eg. pully
- **Body forces**
  - These are distributed over volm of a body. eg. shaft



LOAD

W.R.T. TIME

- Static load
  - DEAD LOAD
  - Gradually Applied load
- Dynamic loads
  - Impact or shock or suddenly App. load
  - Fatique (or) Cyclic (or) Variable load.

Based on dirn of load wrt cross-section

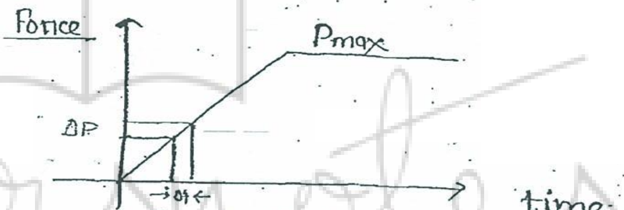
- Normal load
  - Axial load
  - Eccentric Axial load
  - (both →) Tensile, Compressive
- Shear load
  - Transverse shear load
  - ECC. T.S.L.

W.R.P. Distribution of load :-

- Concentrated loads
  - Concentrated point load.
  - Concentrated moments
- Distributed load
  - UDL
  - U.V.L.
  - U.D.M.

tatic load :- When load mag. and dirn are remains const.
ynamic load :- When load mag. and dirn are continuously changes.
:A.L :- When load gradually increases w.r.t. time (mag. varies 0 → max

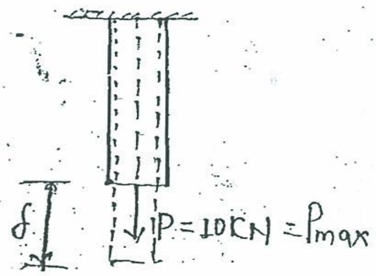
Dead load
eg:- Wt of structural, m/c compo.



Gradually load
(Variation in mag. of load w.r.t. time negligible)

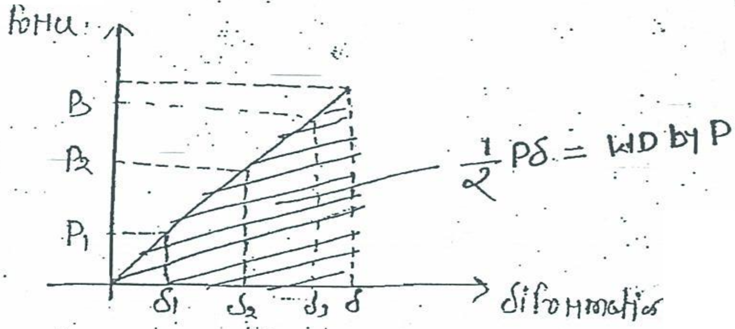
⇓

Impact or suddenly applied load

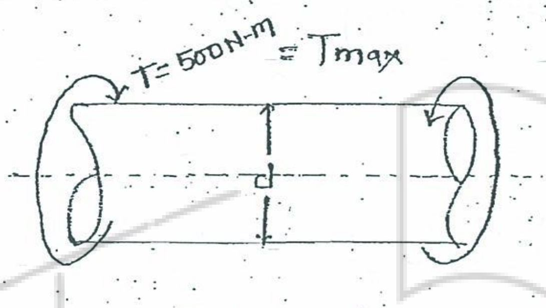


EVERY gradually applied load is represented on component by its maximum magnitude.
(workdone is considered as avg. workdone in the entire scm)

Workdone by P $= \frac{1}{2} P\delta$



eg



W.D. By 'T' $= \frac{1}{2} T\theta$

IMPACT LOAD:- Impact load is a load which is acting for short interval of time.

impact is always fn of velocity

(Hence to overcome this difficulty we use helical gear at high velocity.
eg. piston of ic engine, connecting rod, punching appln, spring used in shock absorber, spur gear tooth under high pitch line velocity.)

$$\delta_{impact} = \delta_{static} \times I.F.$$

$$\sigma_{impact} = \sigma_{static} \times I.F.$$

$$I.F. = 1 + \sqrt{1 + \frac{2h}{\delta_{static}}}$$

δ_{static} and σ_{static} by using Som Eqn

$$h = \frac{V^2}{2g}$$

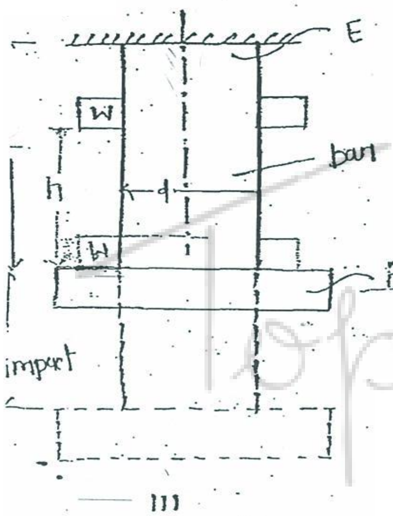
$$I.F. \geq 2$$

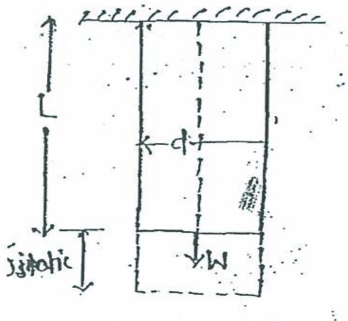
$$\sigma_{impact} \geq 2\,\sigma_{static}$$

$$\delta_{impact} \geq 2\,\delta_{static}$$

$h \rightarrow 0 \Rightarrow I.F. = 2$

(impact load is known as suddenly applied load or instantaneous load)





(1) firstly Assume the given load is the static load.

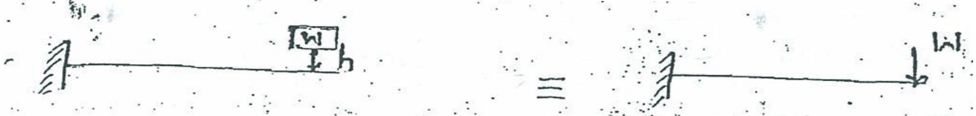
(2) $\delta_{static} = \frac{WL}{AE}$ ——— (1)

(3) Impact factor $= 1 + \sqrt{1 + \frac{2h}{\delta_{static}}}$ ——— (2)

(4) $\sigma_{static} = \frac{W}{A}$ ——— (3)

(5) $\sigma_{impact} = \sigma_{static} \times I.F.$ ——— (4)
$= \text{-------- mpa}$

(6) $\delta_{impact} = \delta_{static} \times I.F.$ ——— (5)
$= \text{---------- mpa.}$



Workdone by load (W) = Strain energy of bar

$$W(h + \delta_I) = \frac{\sigma_I^2}{2E} \times A \times L$$

$\downarrow$
$\left(\frac{\sigma_I L}{E}\right)$

from above eqⁿ

$\Rightarrow \sigma_{st} \propto f(W \text{ and } A)$ i.e. (σ_{static} is independent of L and E)

$A\uparrow \Rightarrow \sigma_{stat}\downarrow$

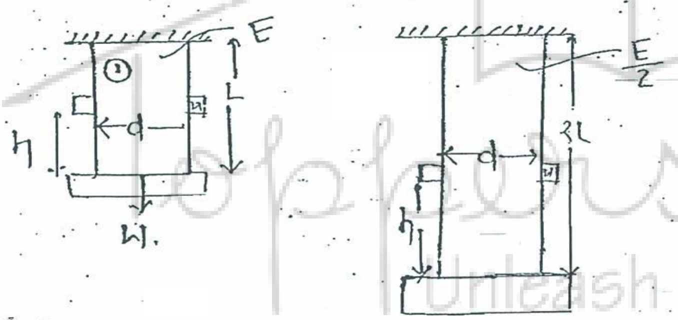
$\Rightarrow \sigma_{imp} \propto f[W, A, L, E, h]$

$E\downarrow, A\uparrow, L\uparrow \Rightarrow$ strain energy of bar increases.

$\Rightarrow \sigma_{impact}\downarrow$

$\Rightarrow$ chances of impact failure $\downarrow$

Q. Both are subjected to Impact load and falling from same height



Static:-

$$\frac{(\sigma_{static})_1}{(\sigma_{static})_2} = 1 \qquad \because W_1 = W_2,\ A_1 = A_2$$

Impact:-

$$\frac{(\sigma_{imp})_1}{(\sigma_{imp})_2} > 1 \qquad \because L_2 > L_1,\ E_2 < E_1$$

$L = 0.5m$

$h = 0.1m$

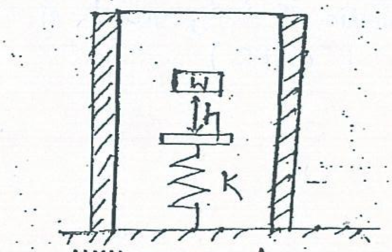
$$\frac{(\sigma_{imp})_1}{(\sigma_{imp})_2} = \frac{(I.F.)_1}{(I.F.)_2} \qquad \left[\because \sigma_{st})_1 = \sigma_{st})_2 = \frac{W}{A}\right]$$

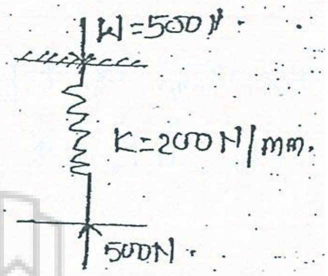
$$= \frac{1 + \sqrt{1 + \frac{2 \times 100 \times 100 \times 200 \times 10^3}{5000 \times 500}}}{1 + \sqrt{1 + \frac{2 \times 100 \times 100 \times 100 \times 10^3}{5000 \times 1000}}}$$

$\simeq 1.95$

For loading as shown in figure determine the maximum height the weight should allowed to fall, such that spring deflection should not exceed 5mm.

(Rigidity criterion should use)





W = 500N
K = 200N/mm (under static)

Assume given load is static

(i) $\delta_{static} = \frac{W}{K} = \frac{500}{200}$

$= 2.5mm$

(ii) $I.F. = 1 + \sqrt{1 + \frac{2h}{\delta_{static}}} = 1 + \sqrt{1 + \frac{2h}{2.5}}$

(iii) Condn for safe,

$\delta_{impact} \leq \delta_{per}$

$\delta_{static} \times I.F. \leq 5$

$2.5\left[1 + \sqrt{1 + \frac{2h}{2.5}}\right] \leq 5$

$h \leq 0 mm$ — Suddenly applied load

let $\delta_{per} = 10$

$\delta_{imp} \leq \delta_{per}$

$\delta_{static} \times I.F. \leq 10$

$2.5\left[1 + \sqrt{1 + \frac{2h}{2.5}}\right] \leq 10$

$h \leq 10mm$

Fatigue load :- Fatigue loads are those load whose magnitude or direction or both magnitude and direction changes wrt. time and these loads are repeatedly applied wrt. time.

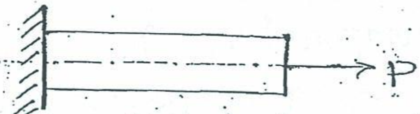


fig:- Static load

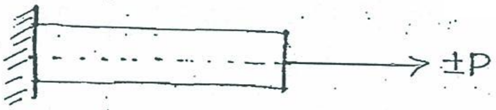


fig:- Completely reversed fatigue load
(only direction of load changes)
mag. remains const

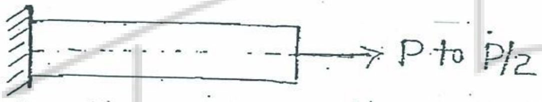


fig. fluctuating fatigue loads
(only mag. of load changes)

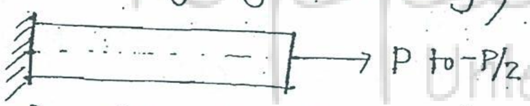
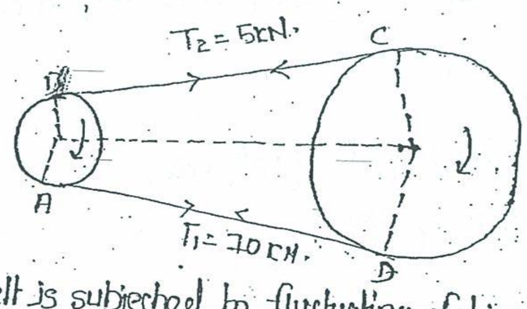


fig. Alternating fatigue loads
(both mag. and direction changes)

Example :-



belt is subjected to fluctuating fatigue load.