MADE EASY

Mechanical Engineering

Toppers Handwritten Notes

MACHINE DESIGN

By-Padmesh Sir

MACHINE DESIGN (MD)

or

MACHINE ELEMENT DESIGN (MED)

or

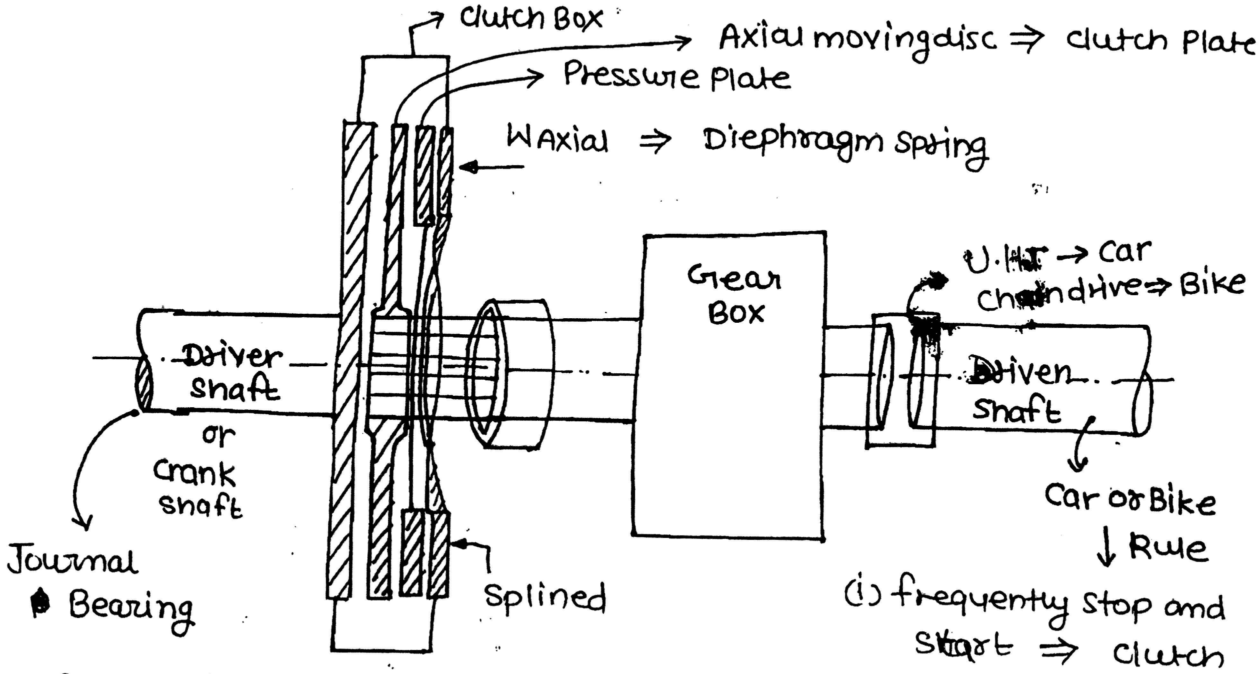
DESIGN OF MACHINE ELEMENT (DME)

- GATE
  - 6-7 Marks
- ESE
  - Pre → 16-18 marks
  - Mains → 68-70 marks

(i) Clutches
(ii) Brakes
(iii) Gear ⇒ (Spur Gear)
(iv) Riveted Joint
(v) Bolted Joint
(vi) Welded Joint
(vii) Bearing
(viii) Fatigue design of shaft
(ix) Spring
(x) Design of flywheel [only ESE]

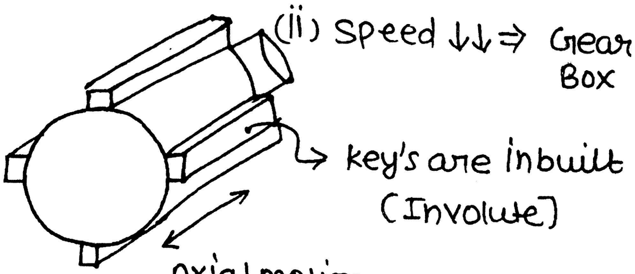
Clutch :→

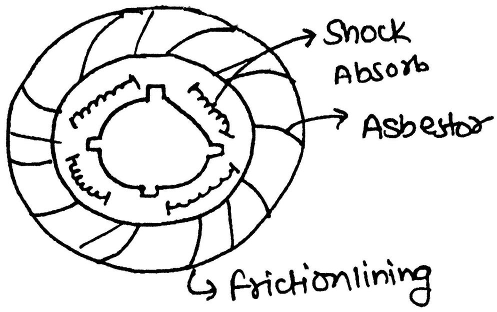
It is defined as a machine element which is use to engage and disengage driver and the driven shaft at the wheel without stopping the Prime mover.

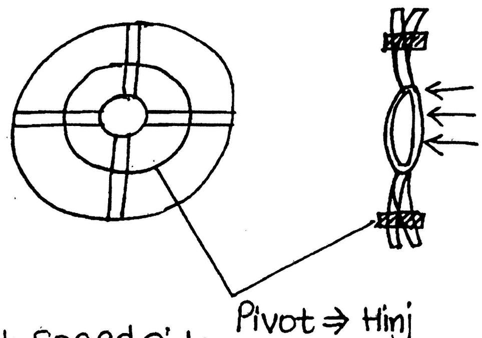


(i) Run continiously
(ii) Speed ↑↑

Car or Bike
↓ Rule
(i) frequently stop and start ⇒ clutch
(ii) Speed ↓↓ ⇒ Gear Box







Q Why clutches are Prefer at High Speed side or engine side ?

Ans → Power $= T_f \times \omega$ ↑↑↑
High speed

$T_f \rightarrow$ Required torque Less
⇓
Clutch design Simple

→ To minimize wear and Losses
Clutch @ Low speed side
Power $= T_f \cdot \omega \downarrow\downarrow\downarrow$
↓
(Torque Required will be more)

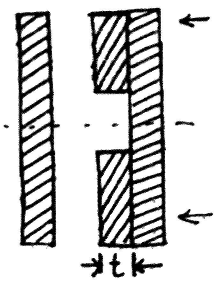
clutch

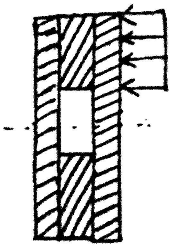
Wear friction is resposible for wear

$\text{wear friction} \propto V$ ↳ Linear velocity

$\text{wear friction} \propto P$ ↳ Pressure

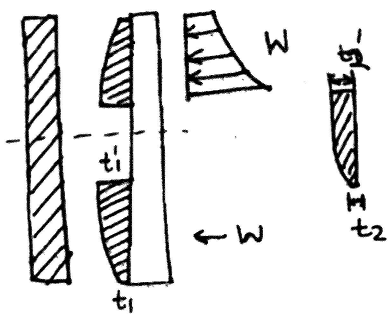
[UPT] NEW CLUTCH (uniform wear नहीं होता है)

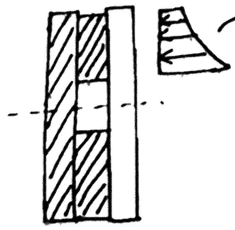




P_{ind} = uniform Pressure
⇓
Perfect Engage

[UWT] OLD CLUTCH (uniform wear होता है।)





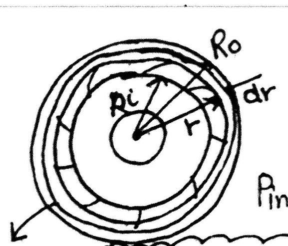
$P_{ind} \rightarrow$ Non uniform Pressure
⇓
Perfect Engage नहीं होता है

Pressure · r = constant ⇒ $P.r = C$
wear friction = constant
⇓
uniform wear Theory (UWT)

$$\int 2\pi r P . dr = \int dw$$

$$2\pi \int_{R_i}^{R_o} \frac{c}{r} \cdot r dr = W \Rightarrow \boxed{c = \frac{W}{2\pi (R_o - R_i)}}$$

$$\boxed{P_{ind} = \frac{W}{2\pi r (R_o - R_i)}}$$



$R_o \rightarrow$ outer radius of Lining
$R_i \rightarrow$ Inner radius of Lining

$$P_{ind} = \frac{W}{\pi (R_o^2 - R_i^2)}$$

$P_{ind} = P$ **uniform Pressure Theory (UPT)** — New Clutch

$$\int_{R_i}^{R_o} 2\pi r \cdot dr \cdot P = \int_0 dw$$

$$\boxed{P_{ind} = \frac{W}{\pi (R_o^2 - R_i^2)}}$$

For Safe Condⁿ
$P_{ind} \le P_{Per}$ (or) P_{allow}

$$\frac{W}{\pi (R_o^2 - R_i^2)} \le P_{Per}$$

$W_{max} = \pi (R_o^2 - R_i^2) P_{Per} \rightarrow$ Strength of New Lining in terms of Load

$t - t_1 > t - t_1'$, $t_1 - t_2 = t_2 - t_2'$

For safe condⁿ
$(P_{ind})_{max} \le P_{Per}$

$\uparrow P_{ind} = \frac{W}{2\pi r (R_o - R_i)}$

$(P_{ind})_{max} = \frac{W}{2\pi R_i (R_o - R_i)}$

$\frac{W}{2\pi R_i (R_o - R_i)} \le P_{Per}$

$W_{max} = 2\pi R_i (R_o - R_i) P_{Per}$
Strength of old lining

New clutch

Frictional torque

$F_r = \mu R_N = \mu dW = 2\pi r dr \cdot p \cdot \mu$

$$\int dT_f = \int_{R_i}^{R_o} 2\pi\mu p r^2 dr = 2\pi\mu p \int_{R_i}^{R_o} r^2 dr$$

$$\boxed{T_{f_{max}} = \frac{2}{3}\mu\pi P_{Per}(R_o^3 - R_i^3)}$$

old clutch

$$\int dT_f = \int 2\pi\mu \cdot p \cdot r^2 dr$$

$$T_f = 2\pi\mu \int_{R_i}^{R_o} \frac{c}{r} \cdot r^2 dr$$

$$T_f = \pi\mu c (R_o^2 - R_i^2)$$

$$c = \frac{W}{2\pi(R_o - R_i)}$$

$$T_{f_{max}} = \mu W_{max}\left(\frac{R_o + R_i}{2}\right)$$

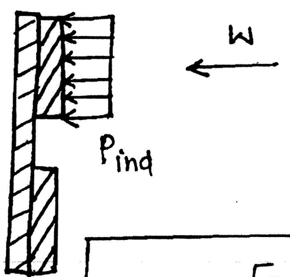
$$\boxed{T_{f_{max}} = \mu\pi P_{Per} R_i (R_o^2 - R_i^2)}$$

NEW CLUTCH ⇒ UPT
⇓
$P_{ind} = c$

OLD CLUTCH ⇒ UWT
⇓
$P.r = c$

New clutch

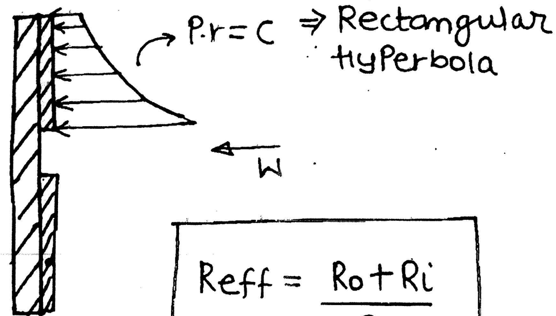
- $P_{ind} = \frac{W}{\pi(R_o^2 - R_i^2)}$
- safe condition
  $P_{ind} \le P_{Per}$
- $W_{max} = \pi(R_o^2 - R_i^2) P_{Per}$
- $T_{f_{max}} = \frac{2}{3}\mu\pi P_{Per}(R_o^3 - R_i^3)$



$$\boxed{R_{eff} = \frac{2}{3}\left[\frac{R_o^3 - R_i^3}{R_o^2 - R_i^2}\right]}$$

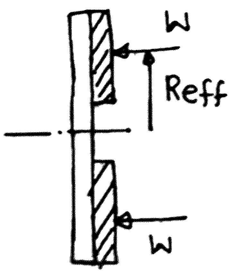
Old clutch

- $P_{ind} = \frac{W}{2\pi r(R_o - R_i)}$
- safe condition
- $(P_{ind})_{max} \le P_{Per}$
- $W_{max} = 2\pi R_i (R_o - R_i) P_{Per}$
- $T_{f_{max}} = \mu\pi P_{Per}(R_o^2 - R_i^2)$



$$\boxed{R_{eff} = \frac{R_o + R_i}{2}}$$

Imagine



$$T_f = \mu W R_{eff}$$

It is an imagamary radius for that we can assume the total friction force or the total Load is Acting

NOTE:

1. Clutch ⇒ Always assume → old clutch
   Hence clutches are design by uniform wear Theory (UWT)
2. Always $T_{f(UPT)}$ is greater than $T_{f(UWT)}$

→ Que → 14/WB/Ch-5

$R_o = 50mm$
$R_i = 20mm$
$\mu = 0.4$
$P_{ind} = 2MPa$

$$T_f = \frac{2}{3} \times 0.4 \times 3.14 \times 2 \times \left[(50)^3 - (20)^3\right]$$

$$T_f = 196\ Nm$$

→ Que → 6/WB/Ch-5

$$5000 = \frac{2}{3}\mu\pi P_{Per}(R_o^3 - R_i^3) \times \frac{2 \times \pi \times 2000}{60}$$

$$5000 = \frac{2}{3} \times 0.25 \times 3.14 \times 10^6 \left[R_o^3 - (0.025)^3\right] \times \frac{2\pi \times 2000}{60}$$

$$R_o = 0.0394m = 39.4\ mm$$

WB/ch-5
Que → 12 Ans: (b)

Q. A single plate clutch use to transmit power in given radial ~~distance~~ space. Find out the Ratio of outer dia. to inner diameter for the lining to transmit max. power

Sol^n

$$P = \frac{2\pi N}{60} \times \mu\pi P_{Per}(R_o^2 - R_i^2)R_i$$

Given Radial Space → R_o → fix

$T_f = f(R_i)$ only

$$\frac{dT_f}{dR_i} = 0 \Rightarrow R_o^2 - 3R_i^2 = 0$$

★ $$\frac{R_o}{R_i} = \frac{D_o}{D_i} = \sqrt{3}$$

For driven

$T_2 = I_2 \alpha_2$

Similarly

$$\frac{d\theta_2}{dt} = +\frac{T_2}{I_2} t + \omega_2 \rightarrow (2)$$

$$\frac{d\theta_1}{dt} = \frac{d\theta_2}{dt}$$

$$-\frac{T_1}{I_1} t + \omega_1 = \frac{T_2}{I_2} t + \omega_2$$

if T_B and T_E are Not Given

$T_1 = T_2 = T_f = T$

$$\boxed{t = \frac{(\omega_1 - \omega_2) I_1 I_2}{(I_1 + I_2) T}}$$ ★

If Driver Inertia 'I_1' is Not given

assume ⇒ $\boxed{I_1 \rightarrow \infty}$

↳ driver speed remains constant

$$\boxed{t = \frac{(\omega_1 - \omega_2) I_2}{T}}$$ ★

→

Que → T3/WB/ch-5

motor ⟶ flywheel

(Driver) (Driven)

$I_1 = ?$ $I_2 = m_2 k_2^2 = 0.3584 \text{ kg-m}^2$

Let us assume driver speed constant ⇒ $I_1 \rightarrow \infty$

$$t = \frac{(\omega_1 - \omega_2) I_2}{T}$$

$$\omega_1 = \frac{2\pi N_1}{60} = 94.24 \text{ rad/s}$$

$\omega_2 = 0$

Power $= T\omega_1$

$T = 9.27$ N-m

$$t = \frac{(\omega_1 - \omega_2) I_2}{T}$$

$$t = \frac{(94.24 - 0)(.3584)}{T}$$

$$\boxed{t = 3.64 \text{ sec}}$$