Rotary Cultivator :-

→ Total power required = power required for rotating + power required for propelling

→ Required rpm 200 – 300 rpm

→ Pulverisation depends upon $\lambda \left(\frac{u}{v}\right)$ i.e $\frac{\text{peripheral speed of rotor}}{\text{forward speed of tractor}}$.

→ The trajectory of the working element of a rotary machine is cycloid so,

$x = Vt + R\cos\omega t$

$y = R\sin\omega t$

R = radius of rotor

V = forward speed of tractor

ω = angular speed of rotor

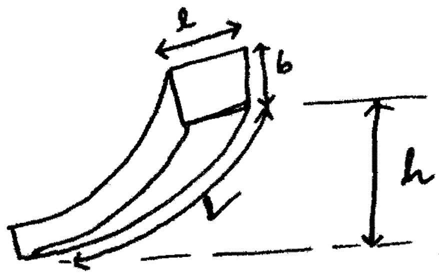
ωt = angle of rotation $= \alpha$

If revolutions are concurrent then the angle α varies from 20° to 100° that means it starts cut from 20° and ends cut at 100°.

If revolutions are reverse the α varies from 260° to 340°.

→ Tilling pitch :-

It's the distance covered during cutting of soil by the consecutive blade of the same rotor of same side.



l = tilling pitch

b = width of cut

h = tilling depth

L = length of cutting.

$$l = \frac{V}{Z \times N}$$

Z = no. of elements operating in one plane of cutting

2 – 3 for rotary cultivators

3 – 4 for rotary hoes & plows

N = no. of revolutions of the working element, rpm

$$u = \pi \times D \times N = 2 \times \pi \times R \times N$$

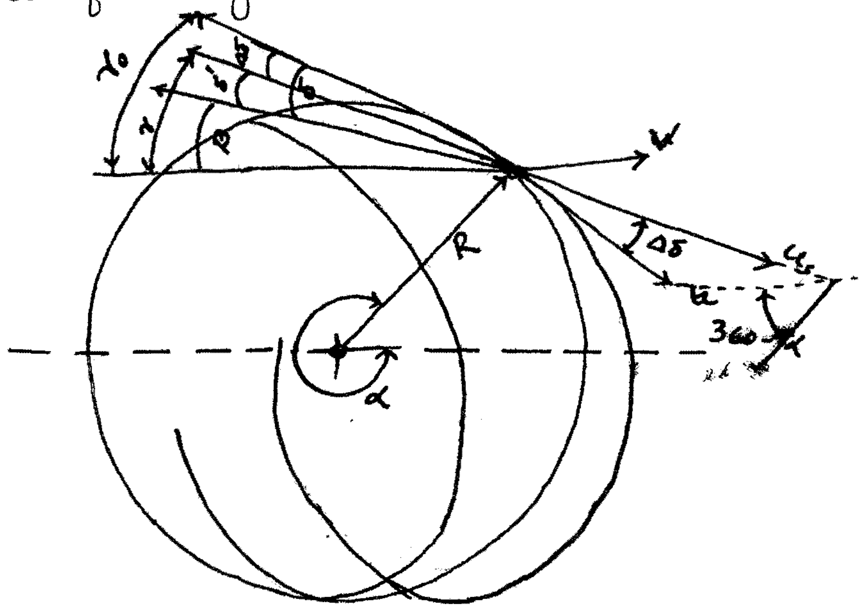
u = peripheral speed of rotor.

$$N = \frac{u}{2\pi R}$$

R = Rotor radius.

$$l = \frac{V}{Z \times \left(\frac{u}{2\pi R}\right)} = \frac{2\pi R}{Z} \times \frac{V}{u}$$

→ Speed and angle of cutting



γ_0 = Setting angle = apparent angle
= angle betn face of blade and tangent to perimeter
= $\beta + \delta$

β = angle of knife sharpening
δ = clearance angle

γ = cutting angle = angle between face of knife and tangent to the cutting ~~path~~ trajectory.

$\gamma_0 > \gamma$ $\quad (\gamma_0 = \gamma + \Delta\delta)$

When blade sharpen from inside, then

$\gamma_0 = \delta$

δ' = effective clearance angle

$\Delta\delta = \delta - \delta'$

Minimum value of $\beta = 10^\circ$
$\delta_{min} = 5^\circ$

U_s = Cutting speed
$= \vec{u} + \vec{v}$ (from the above figure)

$\Delta\delta$ is the angle between u_s and u

$$\tan\Delta\delta = \frac{v\cos\alpha}{u - v\sin\alpha} = \frac{v\cos(360-\alpha)}{u + v\sin(360-\alpha)}$$

$$= \left(\frac{\cos\alpha}{\frac{u}{v} - \sin\alpha}\right)$$

$u_s \cos \Delta\delta = u - v \sin\alpha$

$$u_s = \frac{u - v\sin\alpha}{\cos \Delta\delta}$$

$$= \frac{v\left(\frac{u}{v} - \sin\alpha\right)}{\cos\Delta\delta}$$

for $\frac{u}{v}$ ratio exceeding 5 we can adopt $\cos\Delta\delta = 1$

So, $u_s = v\left(\frac{u}{v} - \sin\alpha\right)$

<u>Note</u>

from the above equation it is clear that if $\frac{u}{v}$ ratio is fixed and the machine having constant forward velocity then cutting speed depends on α.

for concurrent revolution α varies from 20° to 100°

hence $u_s = v\left(\frac{u}{v} - \sin\alpha\right)$

for reverse revolution α varies from 260° to 340°

hence $u_s = v\left(\frac{u}{v} + \sin\alpha\right)$

So that cutting speed [illegible]

Cutting soil is thrown to more distance towards front in case of reverse revolution (due to high cutting speed). And hence it is not generally preferable.

<u>Problem - 1</u>

If $\frac{u}{v}$ ratio is 5 & rotor rotates at 230 rpm & having rotor radius 30 cm, find out the forward velocity of the machine.

$u = 2\pi R N$

$$= \frac{2 \times \pi \times 0.3 \times 230}{60} = 7.23 \text{ m/sec}$$

$\frac{u}{v} = 5$

$$v = \frac{u}{5} = \frac{7.23}{5} = 1.446 \text{ m/sec} \quad \underline{\text{Ans}}$$

→ Forces of cutting soil slices.

$$K = \frac{M}{R'}$$

K = soil resistance
M = Torque acting on shaft.

$$K = \vec{K_x} + \vec{K_y}$$

$$R' = R\cos(\psi - \Delta\delta)$$

avg. value of ψ = 10-15°

$$\vec{K_x} = K\sin(\alpha + \psi - \Delta\delta)$$

$$\vec{K_y} = K\cos(\alpha + \psi - \Delta\delta)$$

We are not taking this relation due to the value of $\Delta\delta, \alpha, \psi$ changes through out the trajection.

So,

$$K_o = \frac{M}{R}$$

K_o = peripheral force
R = radius of working arm
M = ~~Total~~ Mean torque on the shaft.

$$K_o = K_s + K_q$$

K_s = static force to overcome air resistance & friction
K_q = dynamic force for cutting.

→ Specific work.

Work done per one revolution per unit volume of soil handle.

$$A = \frac{2\pi M}{Z \times l \times d \times w} \pm A_x$$

M = mean torque on the shaft, kg-m
A = specific work, kg/m²
Z = no. of working elements
l = Tilling pitch, m
d = depth of working, m
w = working width of machine, m

A_x = draft component or specific draft and can be neglected.

$A = A_0 + A_B$

A_0 = static specific work
and it carried out when the soil slices are being cut off

$A_0 = C_0 \times K_{or}$

C_0 = coefficient (2.5 to 3.5)

K_{or} = soil specific resistance = 0.2 to 0.3 kg/cm^2 (light soil)
= 0.3 to 0.5 kg/cm^2 (Medium soil)
= 0.5 to 0.7 kg/cm^2 (Hard soil)

A_B = Dynamic specific work.
$= \alpha_v \times v^2$ or $\alpha_u \times u^2$

α_v, α_u are the coefficient of dynamic soil resistance
$= 300-500$ $(kg\, s^2/m^4)$

Design:-

1. Width of the blade should not less than 10 cm. $= w_1$
2. Arrangement of blade $= \frac{360°}{i \times Z}$ = Angular interval
   i = no. of rotors
   Z = no. of blade in one rotor.
3. Max. $\frac{1}{4}$ of the total no. of blade can be strike at a time.
4. Working width of machine by using M or K_oR and $A = A_0 + A_B$
5. Shaft diameter by $\sigma = \frac{MY}{J}$
6. Blade dimension by

$$\sigma_{reduced} = \frac{1}{2}\sqrt{(f_{SB})^2 + 4(f_{st})^2}$$

$$f_{SB} = \frac{M_B \cdot Y}{I}$$

$$f_{st} = \frac{M_t}{(J/Y)} \longrightarrow \frac{2}{9}hb^2 \text{ for rectangular cross-section.}$$

$M_t = K_s \times S_1$ $\quad (S_1 = \frac{w_1}{2})$

$M_b = K_s \times S$ $\quad S = R - r_R -$ space for fixing the blade

Design of rotary cultivator:-

Q - For 45 hp tractor design rotary cultivator.

(efficiency from engine to PTO) (20% losses from PTO to rotor)

(1) power required for rotating rotor $= 45 \times 746 \times 0.87 \times 0.8$

power $= K_o \times u$

$=$ peripheral force $\times$ rotor speed.

Assume $\frac{u}{v} = 4.8$

u rotates at 210 rpm

$R = 30\text{ cm}$

$$u = \frac{2 \times \pi \times 0.3 \times 210}{60} = 6.6\text{ m/sec.}$$

$$\text{peripheral force, } K_o = \frac{45 \times 746 \times 0.87 \times 0.8}{6.6}$$

$$= 3540\text{ N}$$

$$\approx 360.87\text{ kg.}$$

(2) $A = A_o + A_B$

$A_o = C_o \times K_{oR}$

for medium soil

$K_{oR} = 0.3\text{ kg/cm}^2$

$C_o = 2.5$

$A_o = (2.5 \times 0.3)\text{ kg/cm}^2$

$= 7500\text{ kg/m}^2$ ——— (i)

$A_B = \alpha_u \times u^2$

$= 300 \times (6.6)^2$

$= 13068\text{ kg/m}^2$ ——— (ii)

$A = 13068 + 7500 = 20568\text{ kg/m}^2$

(3) $$A = \frac{2\pi M}{d \times w \times l \times Z} = \frac{2\pi K_o R}{d \times w \times \frac{v}{u} \times \frac{2\pi R}{Z} \times Z} = \frac{u}{v} \times \frac{K_o}{d \times w}$$

$w = \frac{u}{v} \times \frac{K_o}{\ldots}$ (Assume $d = 0.1\text{m}$)

$$w = \frac{4.8 \times 360.87}{20568 \times 0.1} = 0.842\, m$$ (width of machine)

④ Let blade width = 10.5 cm

The width of one rotor = $2 \times 10.5 = 21\, cm = 0.21\, m$

∴ Total no. of rotor = $\frac{0.842}{0.21} \approx 4$ $+1 = 5$

⑤ Let no. of blades in one rotor = 6

Total no. of blades = $6 \times 4 = 24$ $[3 \times 6 + 2 \times 3] = 24$

Angular interval of blade = $\frac{360}{24} = 15°$

⑥ Shaft design.

$$M = R \times K_0$$
$$= (0.3 \times 360.87) \times 100$$
$$= 10826.1\ kg\text{-}cm$$

Taking factor of safety 1.5

$$M = 10826.1 \times 1.5 = 16239.15\ kg\text{-}cm$$

$$\sigma = \frac{M \times Y}{J}$$

$\sigma = 1000\ kg/cm^2$

$Y = d/2$

$J = \frac{\pi d^4}{32}$ (polar MOI)

$$1000 = \frac{16239.15 \times d/2}{\frac{\pi d^4}{32}} = \frac{16239.15 \times 16}{\pi \times d^3}$$

$$d = \sqrt[3]{\frac{16239.15 \times 16}{\pi \times 1000}}$$

$$= 4.36\ cm$$

Blade design :-

$$K_e = \frac{K_o}{(\text{Total no of blade}/4)} = \frac{360.87}{24/4} = 60.14 \text{ kg}.$$

Taking factor of safety = 1.5

$$K_s = 60.14 \times 1.5 = 90.21 \text{ kg}.$$

$$S = R - r - \text{Space}$$
$$= 30 - \frac{4.36}{2} - 6$$
$$= 21.82 \text{ cm}$$

$$M_B = 90.21 \times 21.82 = 1968.4 \text{ kg-cm}$$

$$f_{sB} = \frac{M_B \times Y}{J} = \frac{1968.4 \times h/2}{h^4/120}$$
$$= \frac{1968.4 \times 60}{h^3} \quad \text{— (i)}$$

$Y = h/2$ $\quad b/h = 1/10$

$J = \frac{bh^3}{12}$ $\quad b = h/10$

$J = \frac{h^4}{120}$

$$M_t = K_s \times S_1 = 90.21 \times \frac{10.5}{2}$$
$$= 473.6 \text{ kg-cm}$$

$$f_{st} = \frac{M_t}{(J/Y)} = \frac{473.6}{2/9\, h b^2} = \frac{473.6}{\frac{2}{9} \times h \times \left(\frac{h}{10}\right)^2} = \frac{473.6 \times 100 \times 9}{2h^3}$$
$$= \frac{426240}{h^3}$$

$$\text{Reduced stress} = \frac{1}{2}\sqrt{(f_{sb})^2 + 4(f_{st})^2}$$

Reduced stress = 1000 kg/cm2 (Assume)

$$1000 = \frac{1}{2}\sqrt{\left(\frac{1968.4 \times 60}{h^3}\right)^2 + 4 \times \left(\frac{426240}{h^3}\right)^2}$$

$$\Rightarrow (2000)^2 = \frac{(1968.4 \times 60)^2 + 4 \times (426240)^2}{h^6}$$

$$\Rightarrow \quad (1968.4 \times 60)^2 + 4 \times (426240)^2$$