# Design of the Components of A Stationary Power Thresher for Paddy Crop

*Presented by*

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# Design of Components of A Stationary Power Thresher for Paddy Crop

1. Design of threshing unit

   a) Threshing cylinder

   c) Concave

2. Design of grain cleaning unit.

   a) Blower

   b) Sieve

# Distribution of power at different components of the thresher

| S. No. | Name of component | Power distribution range (For 5 HP prime mover) | | Selected value |
|---|---|---|---|---|
| | | Percentage | HP | |
| 1 | Threshing cylinder | 57-64% | 2.85-3.2 | 3 HP |
| 2 | Aspirator blower | 34-40% | 1.7-2.0 | 1.75 HP |
| 3 | Sieve shaker | 2-5% | 0.1- 0.25 | 0.25 HP |

Source: CIAE Data book

# Design of Threshing Unit

## 1. Threshing cylinder

Table 1: Recommended specifications for threshing cylinder

| Particulars | Specification | Selected | Reference |
|---|---|---|---|
| Type of threshing cylinder | Spike tooth or Wire-loop | Spike tooth | CIAE Data book,2004 |
| Peripheral speed of threshing cylinder, $V_c$ | 16-25 m/s | 25 m/s | BIS:1990-1979 |
| Rotational speed of threshing cylinder, $N_c$ | 675-1000 rpm | 1000 rpm | BIS:1990-1979 |
| Capacity (Weight of grain output per kW per hour) | $\geq 90$ kg $kW^{-1}h^{-1}$ | 150 kg/kW/h | BIS 6320:1985 |

## Calculation:

1. Diameter of cylinder $D_c = (V_c \times 60)/\pi N_c$

$$= 25 \times 60/\pi \times 1000$$

$$= 0.477 \text{ m} \approx 500 \text{ mm}$$

# Length of threshing cylinder:

Length of cylinder can be determine by the model given by E. I. Lipkovich

$$L_c = q/\Delta \times \eta \times \rho \times u_1$$

Where,

$L_c$ = Length of threshing cylinder, (m)

$q$ = Material feed rate; (kg/s),

$\Delta$= Thickness of the plant mass layer at the entrance in meter (equal to the concave clearance at the entrance)

$\eta$ = Coefficient of cylinder length utilization (0.7-0.8),

$\rho$ = Bulk density of plant mass entering; (20-40 kg/m$^3$ Ref. data book and Kargbo F. R., 2010),

$u_1$ = Velocity of plant mass entering(3-5m/s,Databook)

Recommended grain throughput rate for paddy thresher

**=90 kg/ kWh**

Grain to straw ratio **= 1:1.3 to 1:3**

Therefore, the crop throughput rate or material feed rate for 3.0 HP or 2.4 kW thresher -

Throughput rate = (Grain + Straw) × Power available

$$q = (150 + 150 \times 3) \times 2.24$$

**q = 1332 kg/h of crop = 0.37 kg/s**

Length of cylinder will be -

$$L_c = q/\Delta \times \eta \times \rho \times u_1$$

$$L_c = 0.37 / 0.015 \times 0.75 \times 30 \times 5$$

$$\mathbf{L_c = 0.624\ m \approx 650\ mm}$$

# Arrangement of Threshing Elements on Cylinder bar

Total number of elements can be calculated by the equation-

$$Z = M_P \times \left(\frac{L_C}{a_o} + 1\right)$$

Where, Z = Total number of teeth,

$M_P$ = Number of helical pitches (number of bars on the periphery of the cylinder ring whose teeth tracing the same path), Recommended value = 3 to 5. Selected value $M_P = 3$

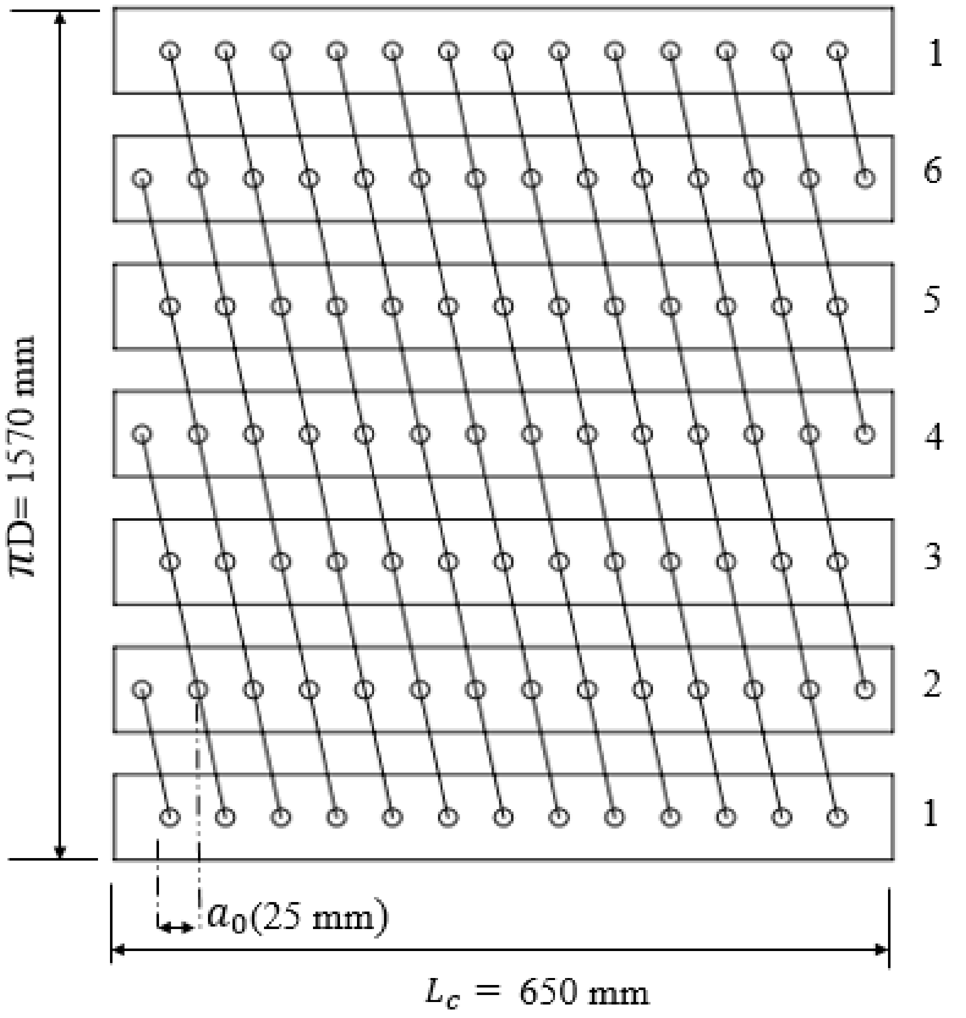
$L_C$ = Length of threshing cylinder, (mm);

$a_o$ = Length of longitudinal pitch, (Recommended value 25-37.50mm, IS:3327- 1982 . Selected value = 25mm ).

Calculation:

$$Z = 3\times\left(\frac{650}{25} + 1\right)$$

Z = 81 elements




Helical arrangement of threshing elements

# Design of Concave

Table2. Recommended specifications for the concave

| Parameters | Specification | Selected | Reference |
|---|---|---|---|
| Concave clearance for paddy crop | 15-25 mm | 15 mm | CIAE Data book |
| Clearance between concave bars | 9 mm | 9 mm | CIAE Data book |
| Cross section of concave bar | $6 \times 6$ mm$^2$ | $6 \times 6$ mm$^2$ | CIAE Data book |
| Wrap angle | 30 to 120° | 120° | Kanafojski, 1976 |

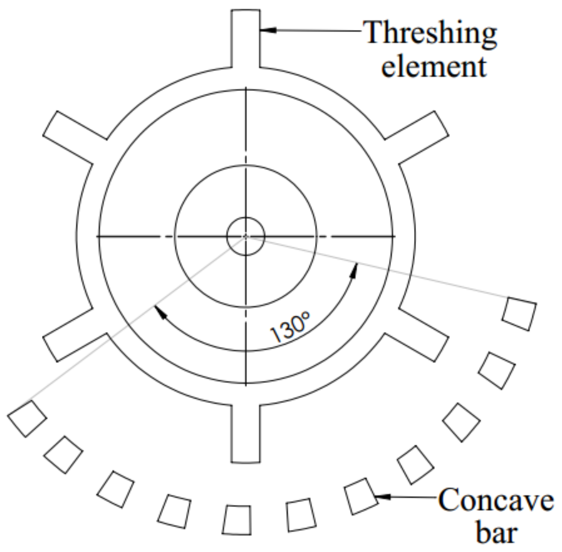



**Fig. 4 Threshing unit**

## Calculation :

Radius of the concave = (radius of the cylinder + Concave clearance)

= (250+15) **= 265 mm**

Wrap angle of concave = length of the concave arc / Radius of the concave

$$120° \times \left(\frac{\pi}{180}\right) = \text{length of the concave arc } /265$$

Length of concave arc = 555 mm

Length of concave arc = (clearance between axial slits + width of the axial slit)× total number of slits

555 = (9+6) × total number of slits

Total number of slits = 37

# Dimensions of feed inlet

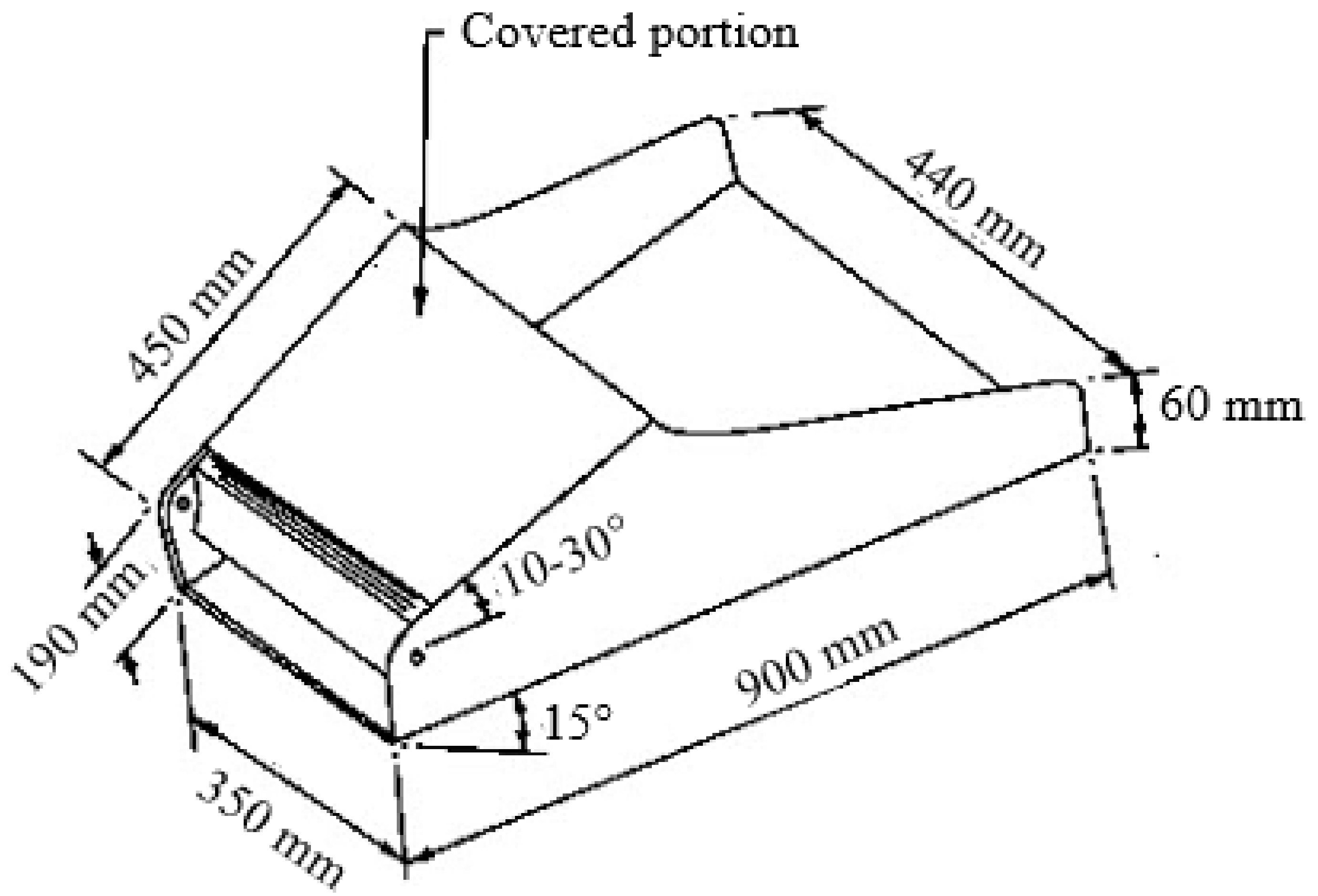
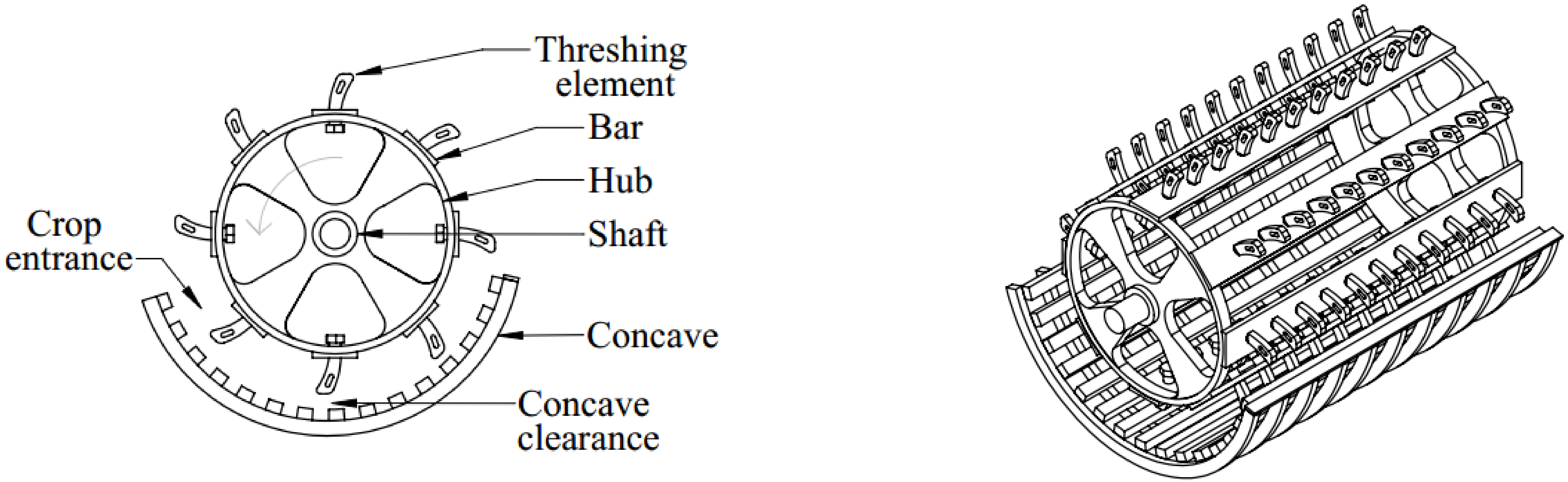
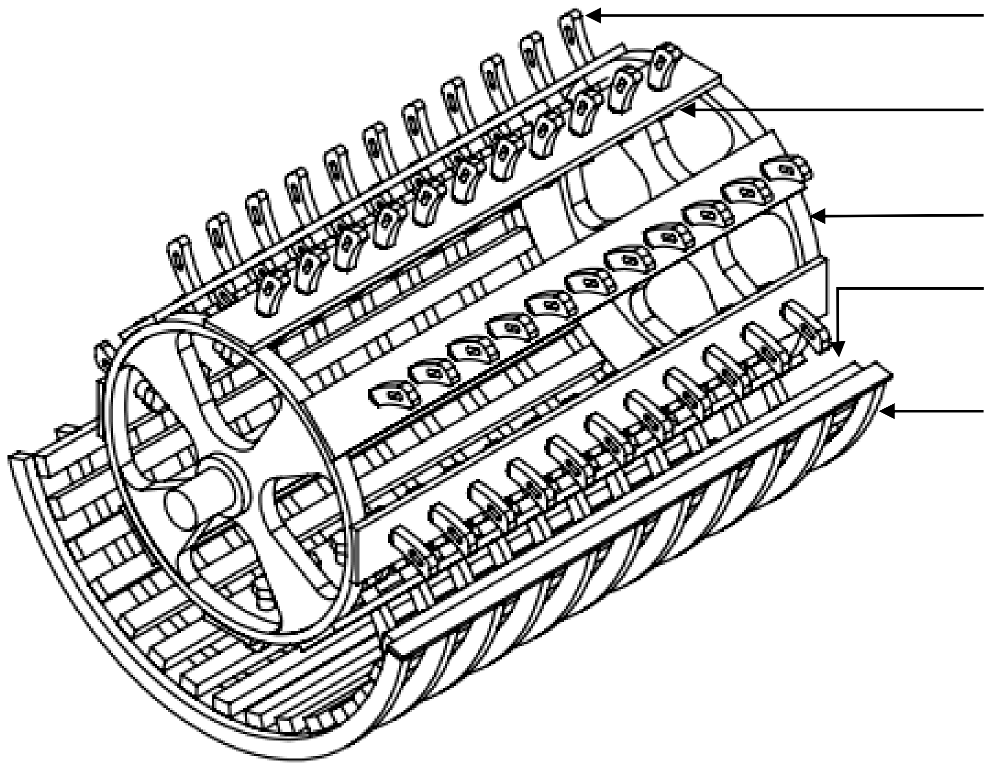



Fig. Dimensions of feed inlet (crop feeding chute) recommended by the Bureau of Indian Standard
IS: 9129-1979 Technical Requirements for Safe Feeding Systems for Power Threshers


Threshing element
Bar
Hub
Shaft
Crop entrance
Concave
Concave clearance



Threshing element
Bar
Ring
Concave clearance
Concave

# Design of Grain Cleaning unit

1. MAIN BLOWER- Function of main blower is to remove straw from threshed mixture.

$M_{MOG} = M_{Straw} + M_{Chaff}$ (Assumption: Total MOG contains 75% straw and 25% chaff)

Thus, $M_{Straw} = 0.75 M_{MOG} = 0.2775 \times 0.75 =$ **0.208 kg/s**, and

$M_{Chaff} = 0.25 M_{MOG} = 0.2775 \times 0.25 = 0.069$ kg/s

Mass of air required to remove the straw per unit time (kg/s) =

$$\frac{\text{Mass of straw removed by air stream per unit time (kg/s)}}{\text{Concentration coefficient of the material entrained by air (0.2 to 0.3, Bosoi. 1990)}}$$

= 0.208 / 0.20 = **1.04 kg/s**

Volume flow rate of air for removal of straw ($m^3/s$) = Mass flow rate of air(kg/s) / Air density ($kg/m^3$)

= 1.04/ 1.275 **= 0.8156 $m^3/s$**

Total mass flow rate = Mass flow rate of straw + Mass flow rate of air

= 0.208 +01.04 = **1.248 kg/s**

# Design of Grain Cleaning unit

Force required to lift the mass (N) = Mass flow rate (kg/s) × Velocity of air (m/s)

= Total mass flow rate (kg/s) × Terminal velocity × Excess velocity coefficient (1.1 to 1.7, Bosoi, 1990)

= 1.248 × 5.25×1.5 **= 8.354 N**

Total Pressure required = Static pressure + Dynamic pressure

$= (\rho \times g \times h) + (1/2 \times \rho \times V_a{}^2)$ (h=AC×tan25)

$= (1.275 \times 9.81 \times 0.325) + 1/2 \times 1.275 \times (7.875)^2 = 4.06 + 39.53$ $\mathbf{= 43.60\ N/m^2}$

Cross sectional area of the duct = Force required to lift the material (N) / Total pressure ($N/m^2$)

$A = 8.354/43.60 = 0.1916\ m^2$

Width of the main blower can be calculated by-

$$\text{Speed of fan(rpm)} = \frac{\text{Volume flow rate} \times 60\ (m^3/s\ )}{\text{Cross sectional area of fan ( } m^2) \times \text{widht of fan blade (m)}} = N_F = \frac{Q_a \times 60}{\pi (r_0^2 - r_i^2) W_b}$$

Assumed that the cylinder and main blower are mounted on the same shaft , therefore rotational speed will same. ($N_C = N_F$ =1000 rpm), Putting the values of speed and volume flow rate in above equation-

$$1000 = (0.8156 \times 60)/\ (0.1916 \times W_b)$$

$W_b$ =0.255m = 255 mm

Therefore, the length of duct cross section = Cross sectional area of the duct/ Width of the duct

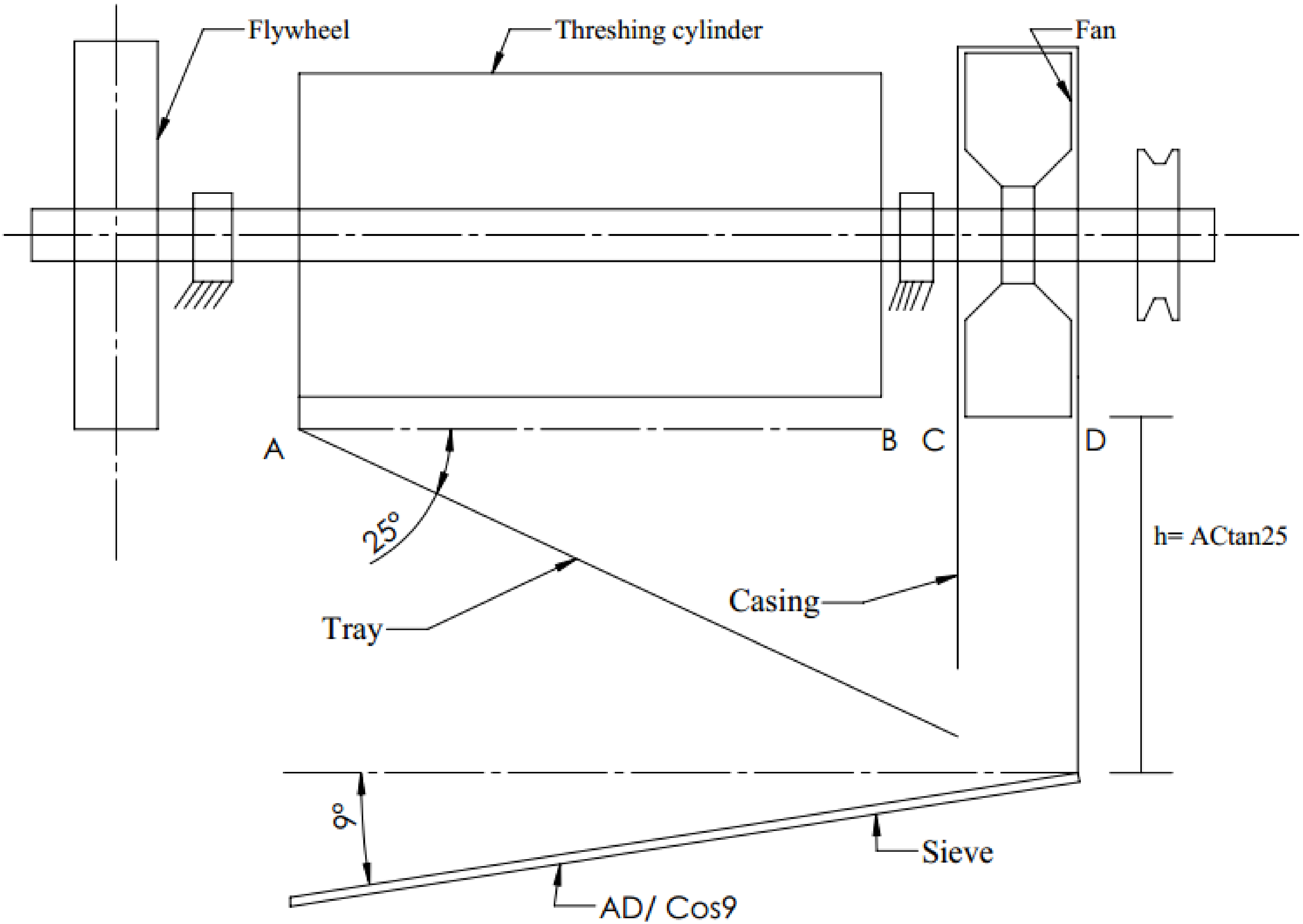
= 0.1916/0.255= 0.75m = 750 mm

The length of he duct cross section = Diameter of the main blower $D_o$= 750 mm

Inner radius of the fan = 0.4× Outer radius of the blower ($r_i = 0.4 \times r_o$)

Thus, $r_o$ = diameter of blower/ 2 = 0.75 m = 375 mm

and $r_i$= 0.4 × 375 = 150 mm



Flywheel
Threshing cylinder
Fan
A
B
C
D
25°
h= ACtan25
Tray
Casing
9°
Sieve
AD/ Cos9

# 2. SIEVE

**Table 3 Recommend values for sieve design**

| Parameters | Specification | Selected | Reference |
|---|---|---|---|
| Diameter of hole | 8 mm | 8 mm | CIAE Databook |
| Sieve inclination | 6-9° | 9° | CIAE Data book |
| Permissible load | 0.65 $kg/m^2s$ | 0.65 $kg/m^2s$ | Bosoi, 1990 |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Length of sieve = AD/ Cos 9

Where AD = length of cylinder +bearing width + fan width

= 650+50+255 = 1140 mm

Length of sieve = 955 / Cos 9 = 970 mm

Width of sieve = Area of sieve / length of sieve

$$\text{Required area of screen for sieving } (m^2) = \frac{\text{Mixture of threshed material delivered (kg/s)}}{\text{Permissible Specific load per unit area } (kg/m^2s)}$$

$= 0.37/0.65 = 0.57\ m^2$

Width of sieve = 0.57/0.97 = 0.587 m ≈ 600 mm

Area of the single opening = $(\pi/4)d^2$ = $50.26 mm^2$

Spacing between opening = $0.9\sqrt{d}$ = $0.9\sqrt{8}$ = 2.54 mm

Pitch of opening = d/2+ edge to edge distance between consecutive opening +d/2 = 4+2.5+4 = 10.54 mm

Number of opening in transverse direction = width of sieve / pitch = 600/10.54= 57

Number of opening in longitudinal direction = length of sieve / pitch = 970/10.54 = 92

Total area of perforation = area of opening × number of openings

= 50.26 × (57 × 92) $mm^2$ = 0.2635 $m^2$

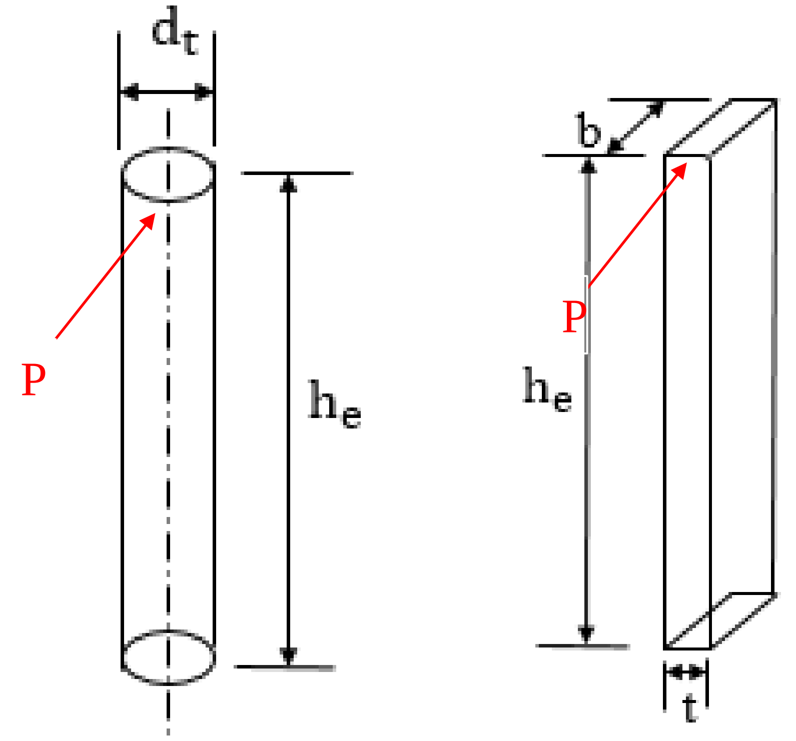
Percentage of opening area = Area of opening/ Total sieve area

= [0.2635/(0.970 ×0.60)] ×100 = 46%

## Design of threshing element:

- Assumptions -

1. Cross section of the spike tooth and peg tooth type threshing elements are circular and rectangular shape, respectively.
2. Threshing element is subjected to bending stress only which is offered by the crop during threshing.
3. The point where the bending force acts is 80 mm above the cylinder bar (height of element, $h_e$)
4. Width to thickness ratio of peg tooth type threshing element b:t =3:1., (t = 0.33b), Kanafojski 1976.
5. Threshing element is made of mild steel has yield stress $\sigma_b$ = 175 MPa.




(a) Spike tooth
Circular cross section

(b) Peg tooth
Rectangle cross section

## Size of threshing element is determined by the equation–

$$\sigma_b / y = M / I$$

Where, $\sigma_b$= Working bending stress of mild steel.

(yield stress/ factor of safety = 175/2.5 = 70 MPa)

(Yield stress = 175 for Mild Steel, CIAE Databook)

y = Distance of neutral axis from the point of application of force; (m),

$d_t/2$ for circular cross section, and b/2 for rectangular cross section,

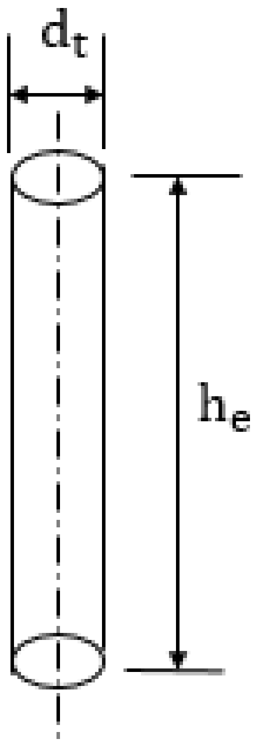
M= Bending moment acting on threshing element; (Nm),

$M = P \times h_e = P \times 0.08$ Nm

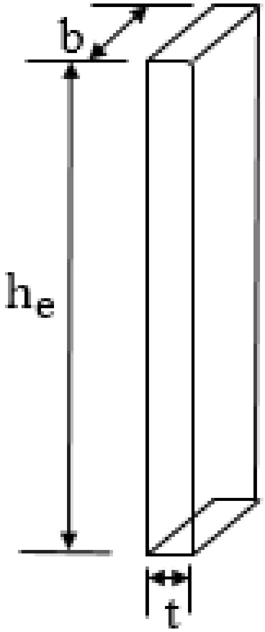
I = Moment of area of cross section $m^4$.

$(\pi/64) \times d_t^4$ for circular cross section, and

$(t \times b^3)/12$ for rectangular cross section



(a) Spike tooth



(b) Peg tooth

Tangential force acting on the element during threshing-

$$P = P_1 + P_2$$

Where,

$P_1$ = Peripheral force appears when the plant mass impacted and brought into motion, calculated by-

$P_1 \Delta t = \Delta m V_P$ (Impulse = Momentum obtained by plant mass, Goryanchkin theory)

$P_1 = (\Delta m/\Delta t).\ V_P = m'.\ V_P$

Where, $\Delta t$ = Striking time; (s), $\Delta m$ = Mass of material struck by tooth; (kg),

$V_P$= Speed of material obtained in time $\Delta t$ , m/s (equal to drum's peripheral speed)

$P_2$ =Resistance force encountered by the drum while displacing the plant mass in the clearance.

$$P_2 = f.P$$

Where, f is the proportionality coefficient of material's rubbing in working slit. (0.7- 0 .8 for peg tooth).

Adding forces $P_1$ and $P_2$

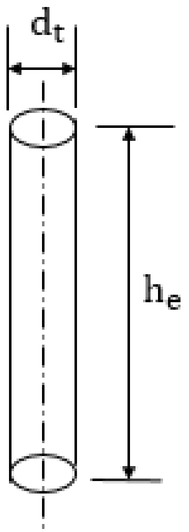
$$P = (m' V_P + f.P)$$

$$P = (m' \times V_p)/(1 - f)$$

$$P = (0.37 \times 25)/(1 - 0.70) = \mathbf{46.25\ N.}$$ Therefore,

**Therefore the bending moment**

$$M = P \times h_e = 46.25 \times 0.08 = \mathbf{3.70\ Nm}$$

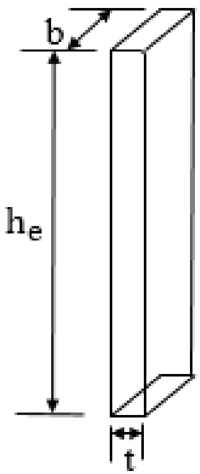



$$\sigma_b/y = M/I$$

$$(70 \times 10^6)/(d_t/2) = 3.70/[(\pi/64) \times {d_t}^4]$$

$$d_t = 8.00\ mm$$

**Circular shaped element**




$$\sigma_b/y = M/I$$

$$70 \times 10^6/(b/2) = 3.70/(t \times b^3/12)$$

$$70 \times 10^6/(b/2) = 3.70/[(0.33b \times b^3)/12]$$

$b = 10.00$ mm and $t = 3.50$ mm

**Rectangular shaped element**

# Design of the shaft

Shaft of cylinder subjected to

1. Torsional stress ($\tau$): Due to tangential force acting on shaft.

2. Bending stress ($\sigma_b$): Due to the weight of the threshing cylinder, blower, flywheel and the pulley.

The combined stress is called equivalent stress.

Torsional stress-

$$\tau = \frac{T \times r}{J} = \frac{T \times (d/2)}{(\pi/32)d^4} = \frac{16 \times T}{\pi \times d^3}$$

Bending stress-

$$\sigma_b = \frac{M \times y}{I} = \frac{M \times (d/2)}{(\pi/64)d^4} = \frac{32 \times M}{\pi \times d^3}$$

Equivalent stress can be calculated by-

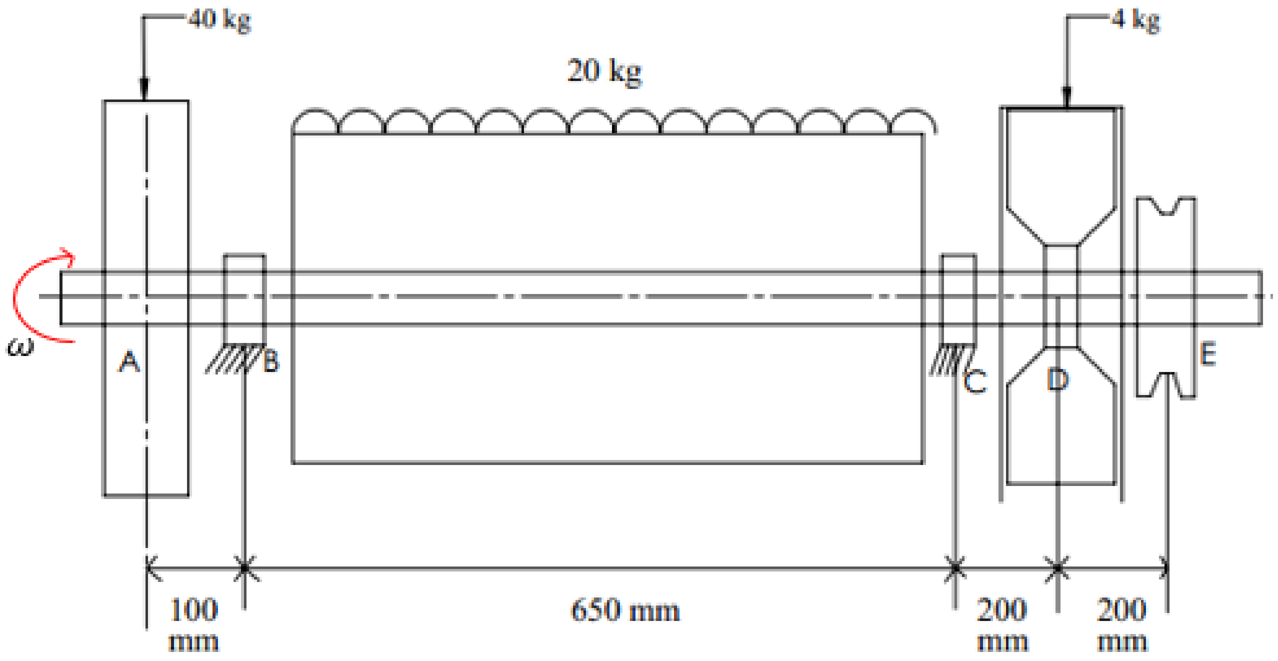
$$\sigma_e = \frac{1}{2}\sqrt{{\sigma_b}^2 + 4.\tau^2} = \frac{1}{2}\sqrt{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left(\frac{16T}{\pi d^3}\right)^2} = \frac{16}{\pi d^3}\sqrt{M^2 + T^2}$$

When shaft is subjected to fluctuating load then the equivalent stress is given by the equation

$$\sigma_e = \frac{16}{\pi d^3}\sqrt{(K_b M)^2 + (K_t T)^2} = \frac{16}{\pi d^3}\sqrt{(1.5M)^2 + (1.25T)^2}$$

$K_b$ and $K_t$ stands for Combined shock and fatigue factor for bending, and Combined shock and fatigue factor for torsion. Respectively, 1.5-2.0 and 1.0 to 1.5 for suddenly applied minor shock

Torque acting on cylinder shaft can be determined by




Power transmitted through belt = 5 hp=3.73 kW

T = Rated power × 60000/ (2πN)

T= 3.73×60000/ (2π×1050) **= 35.61 Nm**

## Bending moment at different point of the shaft

1. Bending moment due to weight of flywheel at point B-

$$M_{AB} = W_A \times L_A = (40 \times 9.81) \times 0.1 = 49.05 \text{ Nm}$$

2. Bending moment at length AC due to weight of cylinder (UDL)

$$M_{BC} = (W_c \times L_c)/8 = (20 \times 9.81) \times 0.65/8 = 16 \text{ Nm}$$

3. Bending moment at point C, due to the weigh of fan+ Load due to belt tension

Bending load on shaft due to belt tension

Tmax = (Tt –Ts) × Radius of the pulley mounted of the shaft

35.61 = (Tt –Ts) × 0.05

(Tt –Ts) = 712.2 N

Assumed that tension ratio is Tt:Ts = 3:1

Thus, Ts = 356.10 N and Tt = 1068.3 N

The net horizontal force act on the shaft of the cylinder

T = Tt +Ts = 356.1+1068.3 **= 1424.4 N**

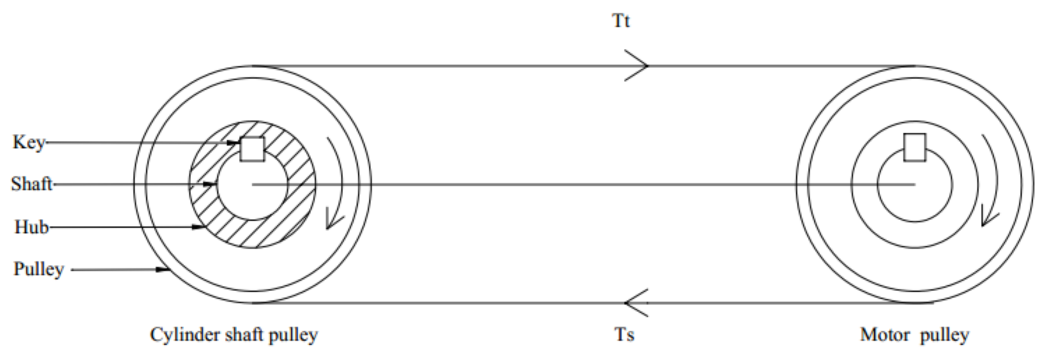



Fig. 3.12 Tension force acting on shaft due to V-belt

Total bending force acting on point C = Load due to fan+ load due to belt tension

= (4×9.81)+1424.4**=1463.64**

The bending moment at point C, $M_{EC}$= Total bending force × Distance (EC) = 1463.64×0.4**= 585.45 Nm**

Therefore,

$$72\times10^{6} = \frac{16}{\pi d^{3}}\sqrt{(1.5\times1463.64)^{2}+(1.25\times35.62)^{2}}$$

d **= 53.77 mm**

# Results

1. Threshing unit
    1. Diameter of threshing cylinder = 500 mm
    2. Length of threshing cylinder = 650 mm
    3. Diameter of circular threshing element = 8 mm,
    4. Width and thickness rectangular = 10 and 3 mm respectively.
    5. Concave radius = 265 mm
    6. Wrap angle of concave = 130°
    7. Diameter of the shaft = 53.77 mm
2. Grain cleaning unit
    1. Inner radius of the fan = 150 mm
    2. Outer radius of the fan = 375 mm
    3. Width of the fan = 255 mm
    4. Length of sieve = 970 mm
    5. Width of sieve = 600 mm

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# Thank you