Design Calculations of the Onion Harvesting Machine**

Data –

1- Width of Digger (w) – 1.1m
2- Depth of Digger (d) – 0.2m
3- Speed of Engine (N) – 2000rpm
4- Speed of PTO Shaft (N') – 540rpm
5- Diameter of Tractor tyre (D) – 1.3m
6- Overall Transmission Ration of Engine (R) – 80:1
7- Shear Strength of Onion Leaves (S) – 1MPa
8- Cutting Area of Blade (A) – 90 sq.cm
9- Crank Radius (r) – 0.07m
10- Connecting Rod Length (l) – 0.21m
11- Mass of Piston (M) – 76.58 kg
12- Density of soil (ρ) – 2000kg/m^3
13- Height of the Belt (h) – 1.45m
14- Thermal Efficiency at 2000rpm (η) = 30%
15- Calorific Value of Fuel (CV) = 45.5MJ
16- Density of fuel (ρ') = 0.832 kg/L

Assumptions –

1- Density of Onion = Density of Soil
2- Θ = Crank Angle
3- Φ = Transmission Angle
4- ω = Rotation Speed of Crank
5- $\dot{m}$ remains constant when onions are fed in Step -2
6- Shaft-Belt Transmission Efficiency = 1

Calculations –

Separator is made of Aluminium.

Since, the onions are forced to go down by the virtue of gravity,

Separator Angle should be greater than Angle of Repose

Angle of Separator = 27°

Angle of Repose = 24°

Since, Angle of Separator > Angle of Repose

$\therefore$ **Onions will slide down**

Speed Of tractor $(v) = (\pi * D * N)/ (60 * R)$

$v = 1.7$ m/s or 6km/hr

Rate of volume of material ploughed $(\dot{m}) = w * d * v$

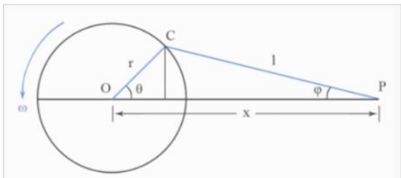
$\dot{m} = 748$ kg/s

Rate of work done on the belt $(P_1) = \dot{m} * g * h$

$P_1 = 10.639$ kW

Force required to cut the onion leaves $(F) = S * A$

F = 9kN



$n = l/r = 3$.........Design range of n = 3-5

Inertia force on the piston $(F_i) = M * r * \omega^2 * (\cos(\Theta) + \cos(2\Theta)/n)$

$M * r * \omega^2 = 17.14$

∴ Inertia force > Cutting force

∴ Cutting can take place

$x = r\cos(\Theta) + l\cos(\Phi)$

$r\sin(\Theta) = l\sin(\Phi)$

Torque required $(T) = x * F_i * \tan(\Phi)$

Max. Torque w.r.t Θ (T_{max}) = 0.857kN

Max. Power reqd. for cutting $(P_{max} = P_2) = T_{max} * \omega$

$P_2 = 48.467$kW

Power Required in Step-1 = P_1

Power Required in Step – 2 = $P_1 + P_2$

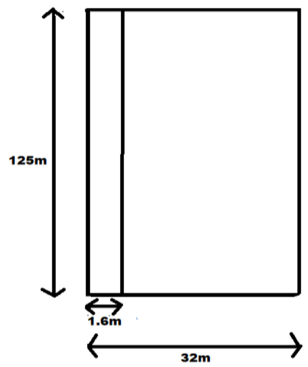
∴ Total Power required (P) = $2*P_1 + P_2$

P = 69.745kW

Mass of fuel required $(\dot{m}_f) = P/ (\eta * CV)$

$\dot{m}_f = 0.0051$ kg/s = 0.3kg/min

Cost per acre of Land -



Patch covered in 1 run= Width of machine + Gap between two patches of onions

= 1.1 + 0.4 = 1.6m

No. of runs = 32/1.3 = 20 runs

Total distance travelled (d') = 125 * 20 = 2.5km

Time required (t) = d'/v = 3.75/6 = 25min

Total Fuel required (M_f) = 7.5kg

Volume of fuel required (V_f) = M_f /ρ'

Volume of Fuel required = 9L

Average Cost of diesel in India = ₹80/L

∴ Total Cost per acre of land = ₹720/-

** The above fuel requirement doesn't consider the excess power required to carry the machine because it will depend on the resistance offered by the soil which can only be calculated experimentally.

References –

1 - *SOLTANABADİ, M. H., ABDOLAHPUR, S., & TAKİ, O. (2012). The Effects of Loading Conditions on Strength and Energy Requirement for Onion Leaf Removing. International Journal of Natural & Engineering Sciences, 6(3).*
2 - *Gomaa, A. E., Mohamed, H. H., El Gwady, A. A., & Al-Aseebee, M. D. (2014). Evaluation of Tractor Diesel Engine Performance using Biodiesel from Three Different Individual Sources. Misr J. Ag. Eng, 31(2), 403-424.*
3 - *Dabhi, M., & Patel, N. (2017). Physical and mechanical properties of Talaja red onion cultivar. Bioprocess Engineering, 1(4), 110-114.*