

Design & Development of Digging, Conveying & Windrowing System for Self-Propelled Onion Harvester

Prof. Dr. A. J. Gujar¹, Pavan P. Sankpal², Sumedh Ghorapade³, Salman S. Desai⁴,
Shubham S. Nakate⁵

Professor, Department of Mechanical Engineering, D.Y. Patil College of Engineering and Technology,
Kasaba Bawada, Kolhapur, Maharashtra, India¹,

Student, Department of Mechanical Engineering, D.Y. Patil College of Engineering and Technology, Kasaba Bawada,
Kolhapur, Maharashtra, India^{2,3,4,5}

ABSTRACT: India is second largest country in producing onion among all popular countries across the globe. The harvesting of onion crop is rigorous and requires huge amount of manpower and time. One of the reasons for lower productivity is insufficient power availability on the farm and low level of farm mechanization. Therefore, with the intension of bringing mechanization, we have developed self-propelled onion harvester which will have good performance in terms of productivity, fuel economy, less damage to crop and operator comfort. Harvester first digs soil around onion bulb, then conveys it to the conveyor and separates soil from onion and then unloads onions. Various factors considered for designing are soil properties, environmental conditions, depth of harvesting, size of onion bulbs and most importantly prevention of damage to onion bulbs. Farm Mechanization reduces unit cost of production through higher productivity.

KEYWORDS: harvester, onion bulbs

I. INTRODUCTION

Digging system to loosening the soil and dig out the onion bulb from the soil without damaging them. Digging unit consist of single uniform blade which digs the soil bed with onions and transport it to soil separating unit. The design of digging blade is based on the soil draft acting on the blade during operation. Working depth of harvesting and properties of material used for manufacturing of blade.

The conveying system designed is itself acts as onion-soil segregation system along with conveying. The conveyor is spacing bar type, it receives soil mass from the digging unit and convey it to windrowing unit

II. METHODOLOGY

Harvesting of onion crop from the field is an important operation, in the cultivation of onion. In our country, few models of onion harvesters developed had an issue of damaging the bulbs of onion, so it was not used by farmers. Non-availability of matching equipment for different farm operations limited the versatility of harvesters. Hence, we focused on developing harvester that not only harvests onions, but also other underground crops like radish, ginger, carrots, etc by simply providing flexible adjustments in the blade geometry according to the depth of particular crop below ground level. A detailed survey was conducted regarding the cultivation of onions and other underground crops by approaching the farmers. This came to conclusion that the average required time to harvest 1-hectare area of onions was 8 hours including labour of 25 workers. The condition of soil (mainly the moisture content) was taken under consideration as it affects the speed of harvesting the crop. Thus, we also focused on designing the digging system for operating even in dry soil condition (10%-20% moisture content). The mentality of the farmers in case of purchasing harvesters was also taken under consideration. Farmers tend to invest their money mostly on a machine that has multi-functionality. A harvester that was able to harvest variety of underground crops was mostly preferred by farmers over those which could harvest only a single crop.

III. DIGGING MECHANISM

Design consideration for digging mechanism

Onion bulb dimensions and working depth: - The working depth for the harvester is decided depending upon onion bulb dimensions in order to prevent the damage to the bulb

Cultivation pattern and crop pattern: - the cultivation of onion is done by using bed furrow bed method. Each bed is 0.75m wide separated by 0.375m wide furrow from adjacent bed. normally bed length is 16m. onion is planted in 5 rows on each bed at 0.15m apart i.e. row to row spacing. Onion is planted 0.10m apart in each row, approximate size of onion (diameter) is between 3 to 6.5 cm and weight 70-80 grams per bulb. The maximum length ranges from 60 to 65 cm particularly lodged from neck of onion bulb.

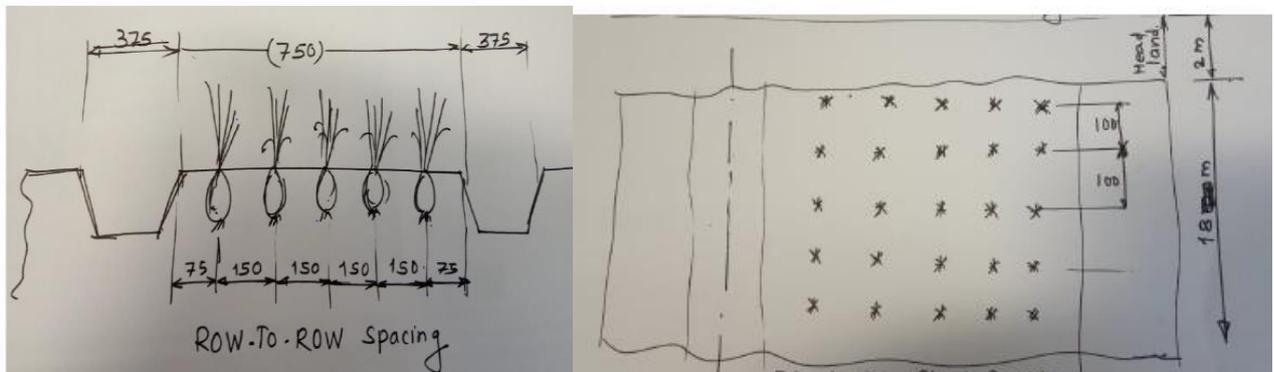


Fig: - Cultivation pattern & crop pattern

Soil specification: - there could be variety of soil depending upon the location of the field, however we have referred values as worst-case scenario for our design

Type of soil – black cotton

Resistance of soil – 0.7 kg/cm²

Characteristics of Black cotton soil

Black cotton soil is generally reddish brown to black in colour. They occur 0.50m to 10 m deep possessing high compressibility.

Table -1: Characteristics of Black cotton soil

S. No.	Property	Value
1	Dry density (yd)	1300 - 1800 kg/m ²
2	Liquid Limit (L.L.)	40 - 120%
3	Plastic Limit (P.L.)	20 - 60%
4	Activity	0.8 - 18%
5	Specific Gravity (G)	2.60 - 2.75
6	Proctor Density	1350 - 1600 kg/m ²
7	OMC (Max Dry Density)	20 - 35%
8	Free Swell Index	40 - 180%
9	Swelling Pressure	50 - 800 KN/m ²
10	C.B.R. (soaked)	1.2 - 4.0
11	Compression Index	0.2 - 0.5
12	Fines (<75μ)	70 - 100%
13	2 μ Fraction	20 - 60%
14	Soil Classification	CH or MH

IV. THERMOTICAL APPROACH FOR BLADE DESIGN

Soehne (1956) analyzed the forces acting on the tillage tool and the soil to develop an expression for the total draft force needed to overcome the various soil reactions. Srivastava et al. (2006) have presented the work by Soehne. Soehne (1956) concluded that soil-metal friction, shear failure, acceleration force for each block of soil, and cutting resistance act on the tillage tool as it moves through the soil. Figure (2) shows a free body diagram of a segment of soil as it reacts to the advancing tool.

The specific draft force (D^*) is defined as: $D^* = D - kb$

$$D^* = \frac{W}{z} - \frac{C A_1 + B}{z (\sin \beta + \mu \cos \beta)}$$

Where

D = Tool support horizontal force

K = Cutting resistance

W = Soil weight = $ybd + \left(L_0 + \frac{L_1 + L_2}{2} \right)$

C = soil cohesion, Pa

A_1 = Area of forward shear failure surface, m^2

Y = wet bulk density = $1800 \text{ kg}/m^3$

B = Tool width

d = tool depth = $0.007m$

L_0 = blade length = $0.84m$

$L_1 = d \{ [\cos(\delta + \beta)] / \sin \beta \} m = 0.0646m$

δ = Tool life angle = 17°

β = Angle of forward failure = $90 - \phi/2$
 $= (90 - \frac{3.08}{2})$

μ = Coefficient of internal soil friction = $\tan \phi$.

μ' = Coefficient of soil-metal friction.

γ = wet bulk density of soil, kg/m^3

L_0 = blade length, m

$L_1 = d \{ [\cos(\delta + \beta)] / \sin \beta \}$, m

$L_2 = d \cdot \tan \delta$, m

ϕ = Angle of internal friction = 3.08

V_0 = Tool velocity

G = acceleration due to gravity, $9.81 \text{ m}/s^2$

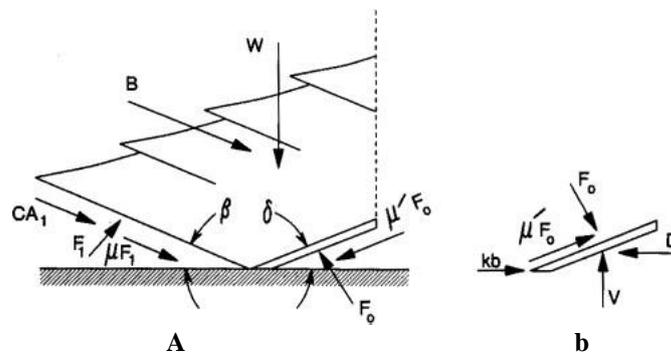


Fig. (2): Soil and tool reaction forces (free body diagram of a segment of soil as it reacts to the advancing tool).

When calculated the required force to dig the soil, it was taken the following parameter:

W = Soil weight N

$$W = ybd^* \left[L_0 + \frac{L_1 + L_2}{2} \right]$$

$$W = 1800 \times 0.1086 \left[0.84 + \frac{0.0646 + 0.0895}{2} \right]$$

$$= 50.8 \text{ N}$$

$$Z = \left(\frac{\cos \delta - u' \sin \delta}{\sin \delta + u' \cos \delta} + \frac{\cos \beta - \mu \sin \beta}{\sin \beta + \mu \cos \beta} \right)$$

$$Z = 1.0610$$

$$\mu' = 1.5$$

$$\mu = \tan \phi = 0.2038$$

$$C = \text{cohesion of soil} = 6846.6 \text{ Pa}$$

$$A_1 = \text{area of forward sheet failure}$$

$$= \frac{b \times d}{\sin \beta}$$

$$= \frac{0.07 \times 0.1}{\sin(39.25)}$$

$$= 0.037 \text{ m}^2$$

$$B = \text{acceleration force}$$

$$= \frac{v}{g} \times b \times d \times V_0^2 \times \frac{\sin \delta}{\sin(\delta + \beta)}$$

$$= \frac{1800}{9.81} \times 0.1 \times 0.08 \times 0.083 \times \sin(17) (\sin 17 + 39.15)$$

$$= 0.0175 \text{ m}^2$$

$$\text{Density } (\rho) = 1800 \text{ kg/m}^3$$

$$\text{Area} = 0.27$$

$$V = 0.83 \text{ m/s}$$

$$\text{Blade Angle } (\Theta) = 17^\circ$$

$$\text{Angle of Forward Failure } (\beta) = 43.46^\circ$$

$$Z = 1.0610$$

$$\text{Soil Weight } (W) = 50.8 \text{ N}$$

$$\text{Cohesion of Soil } (C) = 6846.6 \text{ Pa}$$

$$\text{Area of forward shear } (A_1) = 0.037 \text{ m}^2$$

$$\text{Acceleration Force } (B) = 11.49 \text{ N}$$

$$\text{Internal Friction Angle } (\Phi) = 15.64^\circ$$

$$\text{Drag Force } (D) = W/Z + (C.A_1.B)/Z (\sin \beta + \mu \sin \beta) = 3136.6 \text{ N}$$

Material Selection:

C45 material is kept same as it is as per the prior work as it has all the characteristics that we required. The blade geometry has been cut by laser cutting to achieve precise geometry of blade This has been surface hardened to avoid blade failure in case of shocks

Depending upon above given parameters, the digging blade has been designed and its dimensions are Blade Dimensions (mm) = 810 X 100 X 5

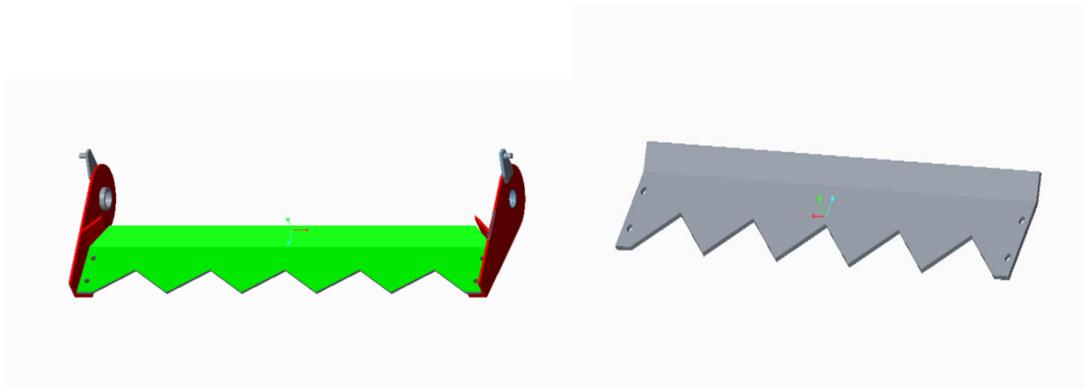


Fig. Blade Geometry with Blade Mountings Fig. Blade Geometry without Blade Mountings



Table -2: specifications of blade

Blade geometry (mm)	810 X 100 X 5
Draft calculations	Bending load = 495N

Mass of soil = 572.119N

Drag force on blade = 2033.59

Bending moment = 304950 N-mm

$$\frac{M}{I} = \frac{\sigma/Fs}{2}$$

$$\frac{527}{\frac{bt^3}{12}} = \frac{280/2}{t/2}$$

$$\frac{527.19}{\frac{800 \times t^3}{12}} = \frac{280/2}{t/2}$$

$$7.9078 t^3 = \frac{280}{t}$$

$$t^2 = 35.07$$

$$t = 5.95 \text{ mm}$$

as per the standard size 7mm is selected.

V. CONVEYING SYSTEM

Supporting plate is attached between the soil separating unit & blade to guide the soil bed with onion on separating unit. Separating unit consist of circular hollow bar arranged lengthwise along the travel of harvester unit. Circular hollow bar is used to reduce the damage of the onion. Spacing between the circular hollow bars is kept 0.025 M to avoid onion falling from this gap. As the length of soil separator increases better separation of soil from onions is obtained but with this the percentage of damaged onions increases. As the soil separator angle increases flow ability of soil in separator increases and soil agitation would be good to obtain good soil separation. Chain & Sprocket drive is used to transfer drive from rear axle to soil separating unit and this unit has odd even combination of teeth and links to facilitate uniform wear. Minimum number of teeth on sprocket are kept to avoid tendency of outward shift of chain

Table-3: specifications of conveying system

Term	Value
Length of conveying unit	mm
Angle of conveyor	30 ⁰
Velocity	0.52 m/s
Spacing between bars	0.025 m
No. of chain links	84
Pitch of chain	19.05 mm
Cross section of spacing bar	14×8

CALCULATIONS

Number of spacing bars = 42

Numbers of links = 84

Therefore, Length of chain = 84 X pitch

$$= 84 \times 19.04$$

therefore $L_o = 1599.37$ mm

Therefore, Centre distance of chain –

$$C_o = 2\pi r + 2C$$

$$C = (L_o - 2\pi r) / 2$$

$$C = (1599.37 - 2\pi \times 51.86) / 2$$

$$C = 636.75$$
 mm

For manufacturing convenience, $C = 630$ mm

But due to Adjustment there will be slag side in the conveyor

Therefore, Slag = 13 mm

Material Selection:

The material of the spacing bar and chain is same as per prior work the conveyor shaft is made of mild steel is an included part of assembly. The reason behind selecting this is M.S. satisfy all the need that we required in terms of bending, as well as in motion.

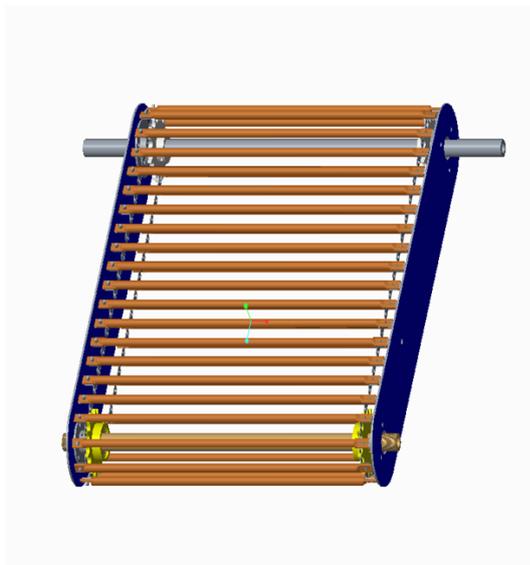


Fig: - Model of conveyor

COLLECTION/WINDROWING SYSTEM

After separating soil from onions, onions are gently dropped on field for curing. It is necessary to keep onions along with tops for curing to remove excess moisture from outer skin and neck to reduce shrinkage and decaying of onion.

INNOVATIVE FEATURES

- Machine is provided with Hydraulic jack mechanism that can adjust height of the digging system as per type of crop to be harvested.
- Electricity generation by means of Solar Energy

VI. CONCLUSION

Onion is the one of the crucial crops in the farming industry in India, which requires more labours and other related expenses .to help the onion farmers to earn some profit and to increase the farmer farming productivity this self-propelled onion harvester is developed

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