IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Design and Development of Self-Propelled Onion Harvesting Machine

Mandar Dilip Shevalkar

Graduate Engineer Trainee
Department of Procurement
Tsubaki Conveyor Systems India Private Limited, Pune, India

Abstract: It is an irrefutable fact that farmers in today's competitive world are facing tremendous problems regarding the harvesting of crops, particularly onions. In India, onions are a majorly grown crop. The traditional method of onion harvesting is time-consuming and requires a lot of manpower. There is a great need for automation in the field of harvesting onions. Self-propelled onion harvesting is well-designed to sustain this need. A unique and well-designed digging, conveyor, and windrowing system are designed that helps in efficient harvesting operations. A proper steering mechanism is designed that helps the driver to safely and accurately steer the vehicle. A chassis or machine frame is selected in such a way that it offers a good balance of toughness, strength, and ductility. The powertrain, being the heart of the vehicle, is integrated with shafts in such a way that power is well distributed across the vehicle. The end result is the smooth and efficient harvesting of onions from the farm with less cost, lessening manpower with increasing of harvesting.

***Keywords* - Machine Frame, Power Transmission Systems, Steering System, Digging System, Conveyor System, Windrowing System.**

I. INTRODUCTION

In India, most of the rural regions are farmers by occupation. They grow various crops throughout the year. India as a country has developed a lot of technologies in each and every field. However, the use of technology by people is quite limited across the country and many of them still rely on manual techniques. The same issue is there in agricultural fields across the country. The Government of India is doing its best and has formed various programs which provide financial aid as well as raise the productivity of crops, which could indeed benefit farmers across the country. Some of the crops which are more frequently cultivated in India are wheat, rice, jowar, pulses, onion, and many more. India is the second largest onion growing in the world. Indian onions are famous for their pungency and are available around the country.

Farmers are facing flourishing problems such as how to increase the productivity of their crops, particularly onions, and how to cultivate more onions in the available time span. A recent study done by The Economic Times states that around 17.5 lakh tons of onion still remain uncut and are still lying-in farms across Maharashtra although the crushing season has ended. What are the solutions to these problems? How can a farmer increase productivity and simultaneously cultivate more crops in less amount of time? The only solution to this problem is using self-propelled onion harvesting machines with a conveyor mechanism. In this research paper, we are going to look up the detailed calculations of the entire self-propelled onion harvesting machine with a unique and cheap conveyor mechanism.

II. MACHINE FRAME/ CHASSIS DESIGN

The materials used for the chassis are AISI 1018 and AISI 4130. The selection of these materials is based on the fact that it has excellent weldability, produce a uniform and harder case, and are considered the best steel for carburized parts. These materials also offer a good balance of toughness, strength, and ductility. Table 1 shows the analysis of the chassis. The CAD Model of the chassis is shown in figure 1.

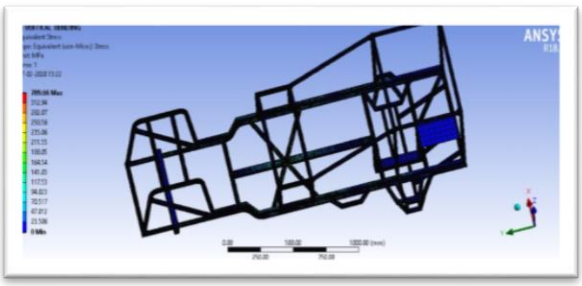

Figure 1 CAD Model of Chassis

G force calculations

N= (N12+ N22)
P/mg=(1+(a/g)2)1/2
=1.73

Table 1 Analysis of Chassis

Analysis	**Max. stress**	**Max. Deflection**	**FOS**
Front torsion	200MPa	1.73 mm	3.75
Rear torsion	300MPa	5.9 mm	2.5
Vertical bending	275 MPa	5.61 mm	2.72
Transverse bending	200 MPa	0.76 mm	3.75

III. DESIGN OF POWER TRANSMISSION SYSTEMS

The powertrain is considered the heart of the vehicle. The power required to run the vehicle and perform various conveyor activities is provided by the diesel engine. The specifications of the diesel engine are given in Table 2. The power transmission in the self-propelled onion harvesting is such that one shaft is attached to the engine, on which a sprocket is mounted, which is connected to the sprocket on the shaft of the gearbox. There is one more intermediate shaft that is directly connected to two shafts, which are the shaft of the gearbox and the conveyor shaft as shown in figure 2.

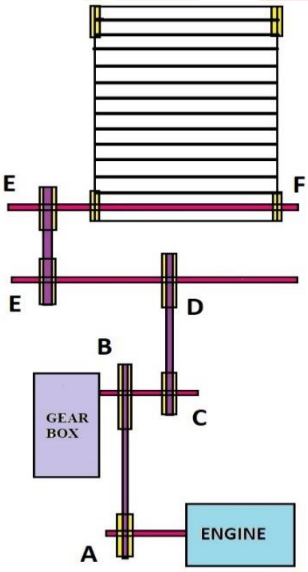

Figure 2 Powertrain Flow Diagram

A. Various Gear ratio calculations: -

The gear ratio of the used gearbox is listed below. The travel speed calculation is given in Table 2.

1^{st} Gear – 1:55.08

2^{nd} Gear – 1:32.72

3^{rd} Gear–1:19.95

Reverse – 1:31.48

For external reduction ratio from Engine output

to Gearbox input.

Reduction Ratio = Engine RPM = $\frac{3000}{1.5}$

Gearbox Input RPM = 2000

B. Sprocket tooth: -

ZA = 14, ZB =21,

ZC=10, ZD=38

Table 2 Travel Speed Calculation

Gear No.	Total Reduction ratio	Speed (RPM)	Speed (Km/hr)	Torque (N-m)
1st	82.62	30.86	4.67	889.54
2nd	49.08	54.95	7.86	528.42
3rd	29.925	85.21	12.89	322.19
Reverse	47.22	36	5.45	598.12

C. Tractive effort: -

Tw =Torque at the wheel

$$Tw= \frac{Nm*\eta 0*TE}{N}$$

Tw = 568.6 N-m

F = Tractive Effort
F = Tw/r =1416.19 N

D. Drawbar pull: -

Rolling resistance (Rr) = w*g*Kr = 971.19 N

Tractive Efforts (F) = 1416.19 N

Drawbar Pull = F – Rr =445 N

E. Gradeability: - G = 100 *$\frac{(F - Rr)}{W}$=80.90 %

F. Brake Calculation: -

Torque Required (Tb) = 315.689 N-m
Torque Generated = 334 N-m
Diameter Calliper = 25.4 mm
Stopping Distance = 1.10 m
Stopping Time = 1.977 sec
Material Used = Asbestos (μ= 0.3-0.4)

The above conditions are satisfied by Bybre disc brake calipers.

G. Chain Drive Selection: -
Pitch = 19.05 mm
PCD of sprocket = 71.35
No of teeth (Na) = 14

IV. STEERING SYSTEM DESIGN

The steering mechanism plays a vital role in the movement of the vehicle in farm fields. The factors which were considered while installing the steering mechanism were the mechanism should be effective and easy to operate, the effort which will be required to steer should be minimal, easy maneuverability, turning radius ≤ 3.5 m and it should be easy to pivot. The steering system specification is given in Table 3.

Table 3 Steering System Specification

Principle	Ackermann
Type of Steering System	Rack & Pinion
Inner Wheel Angle (θ)	40°
Outer Wheel Angle (Φ)	30.38°
Ackermann Angle (α)	14.41°
Turning Radius (R)	3.2m
King Pin Inclination (KPL)	+8
Camber	+2
Caster	+6
Scrub Radius	0.11m
Track Width (a)	1.125m
Wheel Base (b)	1.800m
Kingpin Distance (c)	0.925m
Steering Ratio	18:1

Ackermann's steering mechanism is shown in figure 3. The perfect radius steering geometry condition is

$$\cot\Phi - \cot\theta = (c/b)$$

We have, $\theta = 40°$

$c = 925$ mm

$b = 1800$ mm

$$\Phi = 30.38$$

1. Turning radius of inner front wheel

   (RIF) = (b/sinθ) -((a-c)/2)

   = 2.7 m
2. Turning radius of outer front wheel

   (ROF) = b/sinΦ+((a-c)/2)

   = 3.7 m
3. Actual Turning radius of front wheel

   = (RIF+ROF)/2

   = 3.2 m
4. Ackermann's angle (α) = arc tan[(c/2)/b]

   = 14.41 °

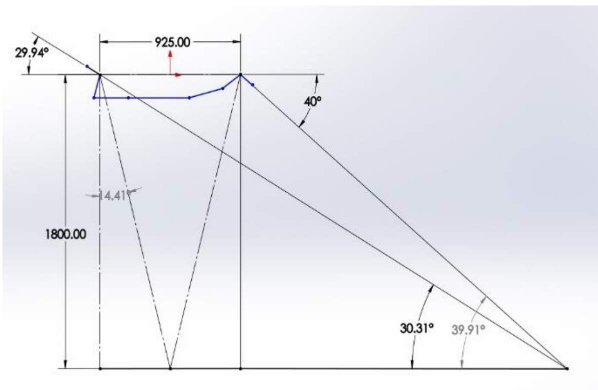

Figure 3 Ackermann's Steering Mechanism

Table 4 Steering Effort Calculation

Factor	Formula	Value
Total weight of the vehicle	(wt. of vehicle +wt. of driver)	500 + 80 = 580 kg
Mass acting at C.G (mCG)	-	232 kg
Mass of each front wheel (mFW)	-	22 kg
Max normal reaction at each front wheel (RA)	((mCG/2) + mFW) * 9.81	1334.16 N
Torque at steering (TA)	μ * RA * (scrub radius)	44027.28 N.mm
Force at tie rods (FT)	{TA/ [(effective length) * cosα]} * 2	2481.298 N
Force along the rack (FR)	FT / cosα	2561.895 N
Torque on pinion (TP)	FR * (pinion radius)	34585.594 N.mm
Torque on pinion (TP)	-	34585.594 N.mm
Effort on steering wheel	TS / (diameter of steering wheel)	230.57 N
Effort on the steering wheel in kg	-	23.503 kg

V. CONVEYOR SYSTEM

The conveyor system is the most important component of the self-propelled onion harvesting machine. It is driven by a diesel engine. The conveyor system consists of three major components which are connected one after another, which allows farmers to remove the crop in a more efficient manner.

This vehicle conveyor system consists of three major components.

A. Digging system

The designed digging system which consists of a number of blades that helps the entire conveyor assembly to advance forward inside the ground is shown in figure 4. The shear blade rack angle i.e., the angle of the blades with the separating system is 20°, which helps the blade to conveniently proceed forward with minimum backward resistance. The experimental field for testing the machine has a width of 750mm. Therefore, the blade geometry selected is 100*140*10mm. Using this blade geometry, 6 blades can be added considering the width of harvesting. The main purpose of manufacturing this machine was to provide farmers with a cheap and highly efficient way to cultivate the crop. So, the digging system used is very simple, unique as well as affordable. The material which is selected for the digging mechanism is EN42 which is a carbon spring steel grade with an average carbon content of 0.70%. The hardness of the material is 107HB.

Figure 4 Digging System Diagram

B. Design Failure of Digging System

A digging system is used to dig out onions from the ground. There are some parameters that can lead to a design failure in digging systems. The potential cause is stones and pebbles in the ground. The effects are that the digging force will increase and cracks will be created. The failure will be the bending of blades and Shear failure of bolts. The action that is taken to avoid this is to change the blades for plastic deformation.

Table 5 Ground Digging System Design

Property	**Calculation**
Blade Geometry	100mm*140mm*10mm
Draft Calculation	Digger Efficiency = 90% Damage Efficiency = 5.96%` Life Percentage = 95%
Shear Blade Rack Angle (α)	20
Width of Harvesting	750 mm
Depth of Harvesting	70 mm
Digger Calculation	Bending Load = 455N Horizontal Components = 1.24*10^3N Vertical Component = 4.45*10^3
Material Selected	EN42
Material Hardness	107HB

C. Conveying system

The next system which is just attached to the digging system is the conveyor system or the separating system. The function of this system is to allow the crops which are removed by the digging mechanism to move backward and are later collected inside the bucket. The type of system which is used here is the roller chain-sprocket conveyor. Two parallel shafts are used. Each shaft carries two sprockets each and through these sprockets, a chain is passed. The power to rotate the conveyor system is provided by a diesel engine. To reduce the cost of the conveyor system, anti-roll bars are used between the front sprocket and the back sprocket as it provides crop support on which they can move backward. The specialty of this anti-roll bar is that it consists of a few numbers of tiny holes in each bar, as with the digging system, the crops are dug but it consists of soil attached to it. The holes in the bars allow the soil to get removed, so what we get is a crop with no soil on it.

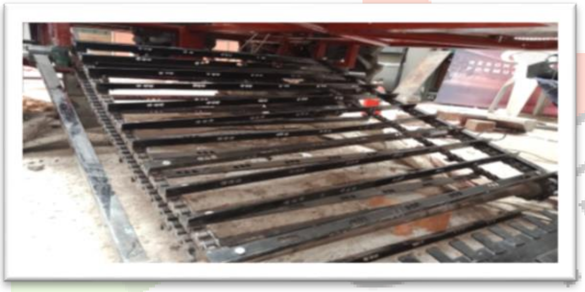

Figure 5 Conveyor System

D. Design Failure of Conveying System

The conveying system is moving the dug onions to the windrowing. There are some parameters that can lead to the design failure of a conveying system. The potential causes are stones, pebbles, and wet soil carried forward by the blades. The effects are that the movement of the conveyor will cease or the movement of the conveyor will slow down due to the obstacles. The failure would be in the sprocket and the chain. The action which can be taken to prevent the failure is covering should be provided in the system.

Table 6 Design of Conveying System

Parameter	**Value**
Type of system	Roller chain-sprocket conveyor
Length of Conveyor	800mm
Width of Conveyor	750mm
Speed of Conveyor	2m/s
Speed of Conveyor shaft	287.75 rpm
Material handling capacity	64.8 Tons/hr
Spacing of Cleaning Elements	20mm
Power Consumption	0.3690 KW

E. Windrowing system

The last component of the conveyor system followed by the conveying system is a windrowing system. The function of this system is to provide a path for the crop to get collected in a bucket which is placed at the backside of the vehicle. This entire system is made to vibrate, as it helps to remove unwanted soil particles, so what we get in the end is a clean crop. The type of system equipped here is the spring suspended gravity discharge system.

VI. INNOVATION IN CONVEYOR SYSTEM

Some of the new technics and innovations which are added to the conveyor system are the Hydraulic system for lifting and lowering the conveyor. The function of this technique is it reduces the efforts made by the driver to lift and lower the conveyor, making sure that one person can manage the entire vehicle. The weight of the entire conveyor is very large, in a condition where the vehicle is moving on farm terrain which is uneven and there can be sudden lifts and holes in the ground. There, this conveyor system should be lifted up or pushed down depending on the ground surface. The lifting and pulling of the conveyor require a lot of strength which cannot be done by manual hands, so here a hydraulic system is used which helps the farmer lift and push the conveyor system.

Figure 6 Windrowing System

Table 7 Windrowing System Design

Parameter	**Value**
Types of system	Spring suspended gravity discharge system
Length	150mm
Top width	750mm
Bottom width	650mm
Speed of operation	Stationary
Output of system	40 onion per rotation of conveyor

VII. FIT, FINISH, ERGONOMICS, AND SAFETY

- Sharp edges have been rounded off and hard points have been covered.
- Electric wires are insulated properly and all moving objects like the chain sprocket have been covered.
- All welds are smooth and the covering is fiber (no use of metal covering).
- Leaks have been prevented by adding oil fills and all leak-prone places are tightened with Teflon tapes.
- Bushing provision under the engine to reduce vibrations.

Figure 7 Neoprene Bushes

Table 8 Explanation of The Top IPC Subclasses

Operator Safety	**Operator accessibility & visibility**	**Operator comfort**
Fire Extinguisher – Amerex B417, 2.5lb ABC Dry chemical class A B C	Easy visibility of conveying and digging	Springs provided under the seat for operator comfort
Chains and Sprocket are covered with a casing of 3mm sheet	Kill switch is easily accessible	Easy Operation of gear System
Kill Switch	Fire Extinguisher is easily accessible	Steering at the optimum distance from the driver
A firewall provided behind the driver's seat	Mirrors	

Figure 8 Leg Room, Kill Switch, and Fire Extinguisher

Figure 9 Firewall

VIII. IMPLEMENTATION

The Self-propelled onion harvesting machine was run on the field which was prepared on the college premises. The field was prepared which consists of wet soil and stones and mud, the same as the land on the actual farm. The outcome was that the work of self-propelled onion harvesting was carried out successfully with no obstacles and the harvesting of onions was done in a well-efficient manner, leading to maximum productivity and that, too, in a time-efficient manner.

IX. CONCLUSION

The self-propelled onion harvesting machine manufactured is done by considering every single parameter, such as that it should be cheap, affordable, produce maximum productivity, requires less time for onion harvesting and it aims to provide farmers across India a benefit. The major components of the vehicle are the transmission system, steering mechanism, and conveyor mechanism that are selected in such a way that they are easily available, and consist of a high tolerance limit to avoid any damage to the vehicle. The end result is the smooth and efficient harvesting of onions from the farm with less cost, less manpower used, and a faster rate of harvesting.

X. REFERENCES

[1] Mahesh, C.S., 2014. Development and performance evaluation of a digger for harvesting onion (Allium cepa L.). International Journal of Agric. Eng.

[2] Jafar Massah, Ahmad Lotfi and Akbar Arabhosseini. 2012. Effect of blade angle and speed of onion harvester on mechanical damage of onion bulbs. Agricultural Mechanization in Asia, Africa, and Latin America.

[3] Budhale, K. C., A. G. Patil, V. S. Shirole, S. S. Patil, R. S. Desai and Salavi, S. B. 2019. Design and development of digging & conveyor system for self-propelled onion harvester. International Research Journal of Engineering and Technology.

[4] Ashwini Talokar, V., P. Khambalkar and Kanchan Wankhade. 2014. Design of onion harvester. International Journal & Magazine of Engineering, Technology, Management, and Research.

[5] Mozaffary et al (2019), Design, Construction and Analysis of Onion Harvester machine for Small Farms (In Laboratorial Condition).

[6] Sungha Hong, Kyouseung Lee, Yongjin Cho Wonyeop Park "Development of Welsh Onion Harvester for Tractor" Nov-2014

[7] McLaughlin A and Mineau P. 1995. The impact of agricultural practices on biodiversity. Agriculture Ecosystems and Environment.

[8] Varvel G, et al. 2006. Great Plains cropping system studies for soil quality assessment. Renewable Agriculture and Food Systems.