types of machines for harvesting of root crops have been developed and are available on the market. However, the
cost of such machines is very high and the machine also
has a complex mechanism and parts, and is big. Chavan
et al. (2015) developed a manually operated reaper which
has field efficiency of 66%. Also, the cost of harvesting
was 37% less than cost of the traditional method. In a
tractor operated harvesting machine, the field efficiency
was 77% (Veerangouda et al. 2010). Singh and Singh
(1995) developed a bullock drawn reaper for harvesting
wheat and paddy crops based on an engine-operated
cutting and conveying mechanism. The performance
evaluation of electrical power harvesting with the manual
harvesting was used for rice harvesting (Aung et al.
2014).

Furthermore, harvesters based on solar power and robot
technology were also developed and evaluated for their
performance (Bodele et al. 2015; Iida et al. 2011).

However, in all available practical solutions, the cost
of the harvesting machine is high. Hence, there is a need
to develop a low cost harvesting machine for poorer farmer.
The structure of the harvesting machine should be simple
and the time of harvesting should be less. At the same time,
maintenance should be low. Machines should be easily
operated by both skilled and non-skilled farmers. In this
regards, Srivastava (2015) studied the problems faced by
farmers in harvesting their crops. He undertook a full study
of this field of agriculture and the problems associated
with it. The Asia and Pacific Commission on Agricultural
Statistics (Asia and Pacific Commission on Agricultural
Statistics, Twenty-Third Session Siem Reap, Cambodia.
2010) was organized to discuss small-scale farming across
Asia and to analyze the average income of small-scale
farmers and the difficulties faced by them. An Indian
Government Analysis (Indian Government Analysis 2016)
involved a survey done by the Indian Government during
2015-16. This survey was done to analyze the problems
and gather the data of the Indian farmers. Younus et al.
(2015) studied the root crop harvester made using locally
available material. The machine was tested on fields and
fulfils the major requirements of harvesting. The machine
design was simple and easy to operate. However, the high
crop damage, frequent delay and breakdown were faced

Abstract: In India agriculture is one of the most important
sources of employment for the farmers and almost
everything depends on agriculture. Root vegetables and
crops are hard to remove from the soil and it takes much
of the farmer’s time. Even after removing these crops
manually farmers are not able to achieve 100% recovery
of the crops. When these crops are taken out manually this
process require many precautions from the farmer. Due
to human error approximate 20-30% of root vegetables
and crops are left out in the field. Rich farmers can afford
the proper machinery to cultivate the root crops but poor
farmers are not able to afford such types of machinery.
Hence, the objective of the present study was to design and
simulate low cost root crop harvesting machines for poorer
farmers. The machine consists of a frame, chain drive,
gears, shaft, seed drill ground wheel, plough and storage
container. All the measurements, dimensions and material
selections were taken as per ASTM-A36 and the design hand
data book. The design of the Root Crop Harvester was done
mathematically and finally validated using CAD software.

Keywords: agriculture, Root vegetable, farming, cultivates

1 Introduction

Harvesting machines or equipments are based on
mechanical systems. These machines are classified
on the basis of crops. In this regards, a reaper is used
for cereal grains, threshers for seed and corn picker
for maize harvesting (Bernacki 1972; Anandaraj 2014).
However, in general a harvesting machine consists of
a frame, plough and wheel assembly. Recently various
During testing.

Therefore, the aim of present study was to design, analyse and simulate low cost root crop harvesting machinery for poorer farmer.

2 Nomenclature

S.T: Soil Type  
S.R: Soil Resistance  
T.D: Total Draft  
A: Area of Plough  
Ṗₚ: Power required for plough  
Pₚₑ: Power required to machine on the basis of weight  
TP: Total Power to operate the machine in field

3 Materials and Method

All the measurements, dimensions and material selections were taken as per ASTM-A36 and the design hand data book. The machine consisted of a frame, chain drive, gears, shaft, and seed drill ground wheel, plough and storage container (Figure 1). When the machine went forwards, the plough went into the soil up to 30 to 40 cm and root crops came out. The seed drill ground wheel was used to drive the belt in the machine. Due to the forward motion of the machine, the wheel rotated in the anticlockwise direction. A gear mechanism was arranged to reverse the rotation of the belt. The root crop, after coming out from the soil, was transferred on to the moving belt drive. The crops and soil were separated out on the belt drive. There was inclination of about 20-30 degrees of the belt drive and it was perforated. After the separation, crops were stored in a container.

The steps below were followed to accomplish the objective of low cost harvesting machines for poor farmers:
1. Discussion with local farmer and enquiring about difficulties faced by them during harvesting of root crops.
2. Researching about available machines on the market and their costs along with alternative methods to accomplish harvesting.
3. Discussing the problem and proposed design with the faculties of the Agriculture University and other professors.
4. Final calculation and final design.
5. Simulation and validation using CATIA cad software.

Table 1 presented all parts and elements used to design root crop harvesting machine. The cost of the machine was reduced by 20% as compared to similar available harvesting machines on the market.

Calculation

i) Crop: Onion, Garlic
ii) Depth of root = 150 mm (approx.)
iii) Soil Type (S.T) = Sandy Loamy
iv) Soil Resistance (S.R) = 0.28 – 0.40 Kg/cm²
v) Optimum Speed = 3.5 Km/h

The Total Draft and Power can be determined using Eq. (1) and Eq. (2) respectively

\[
T.D = S.R \times A \quad (1)
\]

\[
P_T = \frac{T.D}{\text{Opt Speed}} \quad (2)
\]

![Figure 1: Block diagram of root crop harvesting machine](image-url)
Design and Simulation of low cost Root Crop Harvester

Power = \frac{\text{Total Draft (T.D) in kg} \times \text{Speed in Km/h}}{75}

Data:

| SR. NO. | Part Name                        | Quantity |
|---------|----------------------------------|----------|
| 1       | Front Wheel Assembly             | 1        |
| 2       | Spur gear small                  | 2        |
| 3       | Reverse mechanism shaft          | 1        |
| 4       | Front Wheel Assembly Right       | 1        |
| 5       | Link                             | 2        |
| 6       | Front wheel bearing              | 2        |
| 7       | Rear Wheel Assembly Left         | 1        |
| 8       | Rear Wheel Assembly Right        | 1        |
| 9       | Frame                            | 1        |
| 10      | Chain Assembly                   | 1        |
| 11      | Plough                           | 2        |
| 12      | Plough link                      | 2        |
| 13      | Plough link 2                    | 1        |
| 14      | B18.2.3.1M - Hex cap Screw, M24 x 3.0 x 45 - 45S | 12  |
| 15      | B18.2.3.1M - Hex cap Screw, M30 x 3.5 x 40 - 40S | 2  |
| 16      | B18.2.3.1M - Hex cap Screw, M24 x 3.0 x 40 - 40S | 4  |
| 17      | IS 6863-27 x 55-B                | 2        |
| 18      | IS 6863-16 x 30-B                | 4        |

\text{Power(HP)} = \frac{226 \times 3.5}{75} = 10.54 HP

10.54hp engine was required to pull the machine.

\text{3. Total Power to operate the machine (TP) in field:}

\begin{align*}
\text{TP} &= P_1 + P_2 \\
\text{TP} &= 5.55 + 10.54 \\
\text{TP} &= 16.09 HP
\end{align*}

16.09HP engine was required to pull the machine in the field.

All the references of data for the calculation were taken from the Data Agricultural Machinery Design (CIAE, Bhopal).

\text{Ethical approval: The conducted research is not related to either human or animal use.}

\text{4 Results and discussion}

The stress analysis of Plough, Wheel Assembly Link and Plough Link are depicted in Figure 2, Figure 3 and Figure 4 respectively. The plough model with force diagram is shown in Figure 2(a) and the von Mises Stress along the tangential direction is shown in Figure 2(b). Figure 2(b) clearly indicated that fewer stresses were developed in the plough. Thus, the material of the plough was safer during its operation. The configuration of the plough is simulated using CATIA V5. The simulation parameter was two times higher than the original parameter.

The Wheel Assembly Link model and force diagram is shown in Figure 3(a). Displacement diagram and von Mises Stress along the normal directions are shown in Figure 3(b) and Figure 3(c) respectively. On the other hand, The Plough Link model and force diagram is shown in Figure 4(a). Displacement diagram and Von Mises Stress along the normal directions are shown in Figure 4(b) and Figure 4(c) respectively. In both the cases of Figure 3(c) and Figure 4(c), stresses developed in the Wheel Assembly Link and plough link were within the limit and safe. Thus, the material of Wheel Assembly Link and plough will not fail during its operation. The configuration of Wheel Assembly Link and plough link were simulated using CATIA V5. The simulation parameter was two times higher than the original parameter.

\text{Conclusions}

The design, analysis and simulation of the Root Crop
a) Plough Model

*b) FEM von-mises stress in Plough

**Figure 2: FEM Analysis in the Plough**

---

a) Wheel Assembly Link Model

b) Displacement in the Wheel Assembly Link

c) FEM von Mises stress in Wheel Assembly Link

**Figure 3: FEM Analysis in Wheel Assembly Link**

---

a) Plough Link Model

b) Displacement in Plough Link

c) FEM von Mises stress in Plough Link

**Figure 4: FEM Analysis in Plough Link**
Harvesting Machine were performed successfully. The proposed approach was applied to harvest root crops; mainly onion and garlic. The CATIA V5 Software was used for simulation of the optimized shape of the Plough, Wheel Assembly Link and Plough Link. It was concluded that after applying two times more parameters, the parts design was safe during operation. On the basis of cost of parts used in the proposed machine, it can be further concluded that the cost of the proposed machine was 20% lower than the cost of a similar machine on the market.

Conflict of interest: Authors declare no conflict of interest.

References

Anandaraj M., ICAR-Indian Institute of Spices Research, Kozhikode, Kerala, 2014

Asia and Pacific Commission on Agricultural Statistics, Twenty-Third Session Siem Reap, Cambodia, 2010

Aung N.N., Myo P.P., and Moe H.Z., Field performance evaluation of a power reaper for rice Harvesting, International Journal of Scientific Engineering and Technology Research. 2014, 12(3), 2631-2636

Bernacki H., Haman J. and Kanafojski C., Agricultural Machines, Theory and Construction. Vol. 1, Scientific Publications Foreign Cooperation Center, Warsaw. 1972, 513

Bodele P.L., Bhadane R.G., Barhate P.R., Bachhav V.A., Mali B.G., and Bhane A.B., Pollution free solar powered brush cutter. International Journal of Emerging Technology and Advanced Engineering. 2015, 5(5), 153-156

Chavan P.B., Patil D.K., Dhondege D.S., Design and development of manually operated reaper, IOSR Journal of Mechanical and Civil Engineering. 2015, 12(3), 15-22

Data Book for Agricultural Machinery Design CIAE, Bhopal, 2004

Hyde G.M., Solid and perforated rotary blade performance on a potato harvester, ASAE, 1986

Iida M., Yamada Y., Rice harvesting operation using an autonomous combine with a GPS and a FOG, Proceedings of the Conference of Automation Technology for Off-road Equipment, ASAE, 2006, 125-131

Kang W.S., Halderson J.H., A vibratory, two-row, potato digger. Applied engineering in agriculture, 1991, 683-687

Kulkarn D.S., Mechanization of Agriculture - Indian Scenario. Mechanisation of Agriculture- Indian Scenario. Proceedings of the conference on the Technical Committee of APCAEM (21-24 November), New Delhi, 2007, 1-29

Muhammad Y., Mehmood A.M., Rehman R., Design development and performance evaluation of rotary potato digger. AMA, 2003, 43-46

Nasre I. M., Potato wastage in Freidan storehouse. 2003, 191-208

Singh T.P., Singh B., Design and development of animal-drawn, engine-operated reaper. AMA. 1995, 26(2), 29-34

Srivastava S.L., Farm power sources, their availability and future requirements to sustain agricultural production. IARI, New Delhi. India, 2004, 36-44

State of Indian Agriculture, Indian Government Analysis, 2016

Veerangouda M., Sushilendra K.V., Anantachar, M., Performance evaluation of tractor operated combine harvester. Karnataka Journal. Agricultural. Sciences. 2010, 23 (2), 282-285

Youhunus A., Jayan P.R., Performance Evaluation of Root Crop Harvesters, IJERD, 2015, 11(06), 38-52