Research Article

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Design and Simulation of low cost Root Crop Harvester

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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 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

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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
P_P: Power required for plough
P_W: 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.

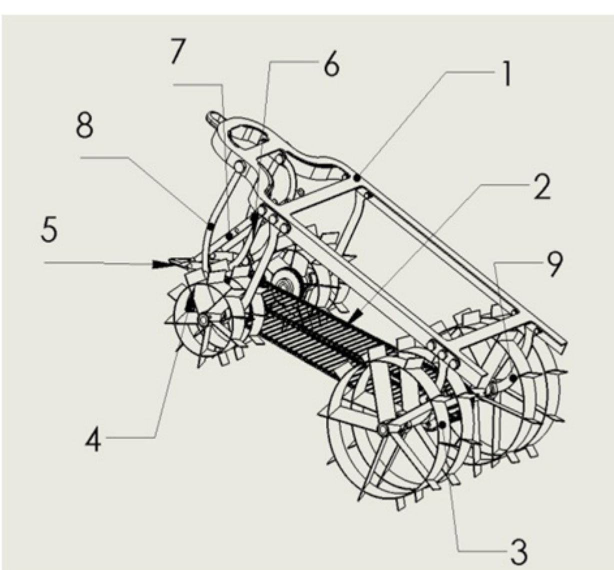
Table 1 presented all parts and elements used to design root crop harvesting machine. The cost of the machine was reduced by 20% as compared to similar available harvesting machines on the market.

Calculation

i) Crop: Onion, Garlic
ii) Depth of root =150mm (approx.)
iii) Soil Type (S.T) = Sandy Loamy
iv) Soil Resistance (S.R) = 0.28 – 0.40 Kg/cm^2
v) Optimum Speed = 3.5 Km/h
6.

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

$$\text{Total Draft (T.D)} = S.R * A \quad (1)$$



SR. NO.	Part Name	Quantity
1.	Main Frame	1
2.	Web Assembly	1
3.	Rear Ground Drill Wheel	4
4.	Front Ground Drill Wheel	4
5.	Plough	1
6.	Plough Link	2
7.	Adjustable Link	2
8.	Gear Shaft Arrangement Link	2
9.	Wheel Assembly Link	4

Figure 1: Block diagram of root crop harvesting machine

Table 1: List of Materials

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	1
12	Plough link	2
13	Plough link 2	2
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

$$\text{Power} = \frac{\text{Total Draft (T.D) in kg} * \text{Speed in Km/h}}{75} \quad (2)$$

Data:

Area of Plough = $0.034m^2$
Length of digging=0.15m
Soil Resistance (S.R) = $0.35kg/cm^2$ [1 kg = 9.80 N]
= $0.35x9.80x10^4$ =34300 N/m^2
Total Draft (T.D) = Soil resistance x Area = 34300x0.034 =1166N (approx.)
Draft in kg = 119 Kg (approx.)

1. Power required for plough:

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

$$\text{Power} = \frac{119 * 3.5}{75}$$

$$P_p = 5.55\text{HP}$$

5.55HP engine was required to plough in harvesting.

2. Power required for machine on the basis of weight:

Total Weight of machine = 226 Kg
Optimum Speed = 4 Km/h

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

$$\text{Power(HP)} = \frac{226 * 3.5}{75}$$

$$P_W = 10.54\text{HP}$$

10.54hp engine was required to pull the machine.

3. Total Power to operate the machine (TP) in field:

$$TP = \text{P1} + \text{P2}$$
$$TP = 5.55 + 10.54$$
$$TP = 16.09\text{HP}$$

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).

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

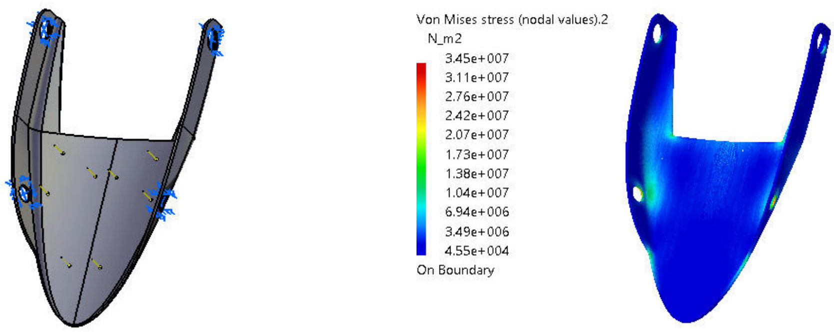
4 Results and discussion

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.

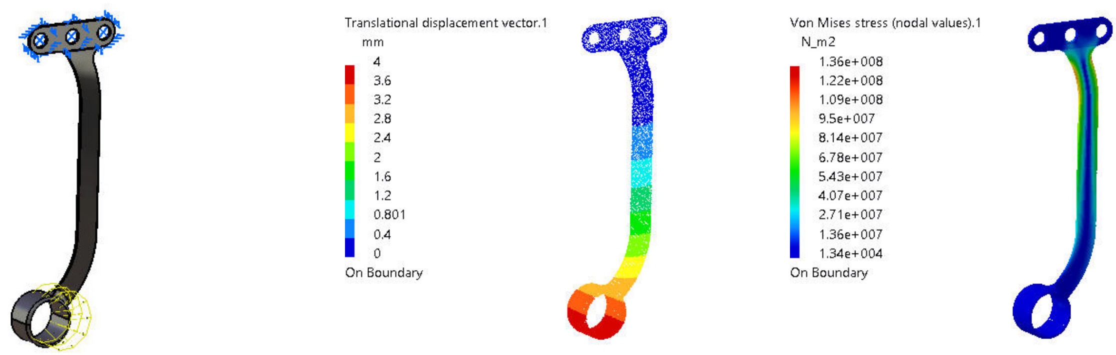
Conclusions

The design, analysis and simulation of the Root Crop



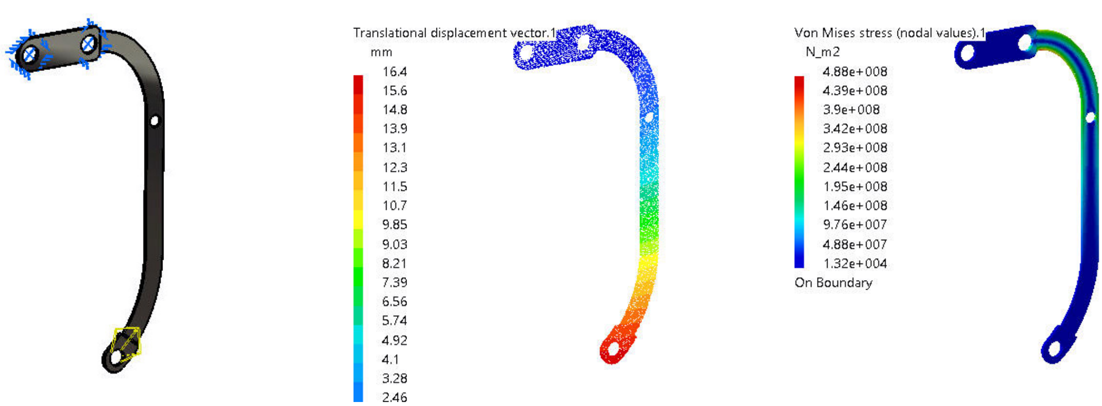
a) Plough Model b) FEM von-mises stress in Plough

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.

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