

# Cassava Harvesting Machine

G. S. Molly Irine<sup>1</sup> E. Mohan<sup>2</sup> P. Mohan Babu<sup>3</sup>

<sup>1</sup>Associate Professor <sup>2,3</sup>Student

<sup>1,2,3</sup>Department of Mechanical Engineering

<sup>1,2,3</sup>IFET College of Engineering Villupuram 605108 Tamil Nadu, India

**Abstract**— Cassava is third-largest important crop and an essential source of food and income throughout the tropics. Now a days Nigeria is world's largest producer of cassava in the world. India being a tropical country, cassava is cultivated in many states of cassava harvesting is the most difficult and cost-intensive process, so the most viable solution to overcome these constraints is to promote the cassava harvesting machine using engine power. Process involved in uprooting cassava were found out from local farmers, studied and mechanized using bevel gears, petrol engine, bearing and sprocket. The machine in running conditions, a shovel is the used for loosening the soil near the stem. The chain mechanism is to be applied for the pulling of stem. The stem is lifted in the upward direction. The cassava harvested uprooted is stored in the tray. This method be used easily and reduces the harvesting cost. These type of machines reduces man power and cost is less. Advantages of this machine include faster uprooting, high productivity, reduces time, cost, labors.

**Key words:** Cassava, Bevel Gear, Shovel, Sprocket

## I. INTRODUCTION

Cassava is commonly known as Tapioca, continues to be a crop food security for the millions of people especially in the developing countries of the globe. Nigeria is the world's largest producer of cassava. Cassava is the third-largest sources of carbohydrates for meals in the world. It is an important alternate source of energy to meets the demands of increasing population. This crop has the potential to produce more food per unit area, capacity to withstand adverse biotic and abiotic stresses and adaptability to the conditions of drought and marginal lands.

The crop has been cultivated in India for more than a century. Cassava was introduced into India by the Portuguese when they landed in Malabar region, presently part of Kerala state during the 17th century, from Brazil. Taking the successful example of Tamil Nadu where cassava has changed itself from food crop to commercial crop, some progressive farmers cum industrialists from east Godavari district of Andhra Pradesh started cultivating and popularizing the crop to produce sago as well as chips for export.

Though rice and wheat form a major part of the staples for Asians, it is to be noted that Asian continent is the second largest in terms of area and production of cassava with a productivity of 16.76 t/ha. South America has 13.44 per cent (third rank) of the world production. Nigeria is having the largest area under cassava (22.25%) among all the cassava growing countries in the world with an annual output of 38.18 million tones. All the major cassava growing countries in the Asia continent have the productivity more than world average productivity. Indonesia, Thailand, India and Vietnam are the major countries growing cassava in Asia.

Tamil Nadu occupies second position in terms of area and production of cassava in India and its productivity is the highest in the world. sixty per cent of the crop is grown under irrigated conditions in Salem, Erode, Namakkal, districts while forty per cent of the crop is cultivated as rain fed crop in these districts. However, the cassava area in Kanyakumari district is mostly cultivated under rain fed conditions.

## II. LITERATURE REVIEW

### A. Design of a Cassava Uprooting Device

Author Name : A.S. Akinwonmi and F. Andoh .Department of Mechanical Engineering, University of Mines and Technology, Tarkwa, Ghana:

This paper analyses the design of a simple, efficient, cheap, affordable cassava uprooting device for local cassava growing farmers.

### B. Comparative evaluation of manual cassava harvesting techniques in Kerala, India

Author Name :Shadrack Kwadwo Amponsah<sup>1</sup>, J. Thajudhin Sheriff<sup>2</sup>, Gangadharan Byju<sup>2</sup>

CSIR-Crops Research Institute, Kumasi, Ghana; 2. ICAR-Central Tuber Crops Research Institute, Sreehariyam, India)

This paper gives a comparative evaluation of the manual harvesting cassava techniques in Kerala. It evaluates the efficiency of four manual cassava harvesting techniques under different land preparation.

### C. Development and prototype trial of digging-pulling style cassava harvester

Author Name: Liao Yulan<sup>1</sup>, Sun Youpan<sup>2</sup>, Liu Shihao<sup>3</sup>, Cheng Danping<sup>4</sup>, Wang Gaoping<sup>1</sup>

- 1) (1.College of Mechanical and Electrical Engineering, Hainan University, Haikou 570228, China;
- 2) Jian'an Branch, China Changan Automobile GroupCo., Ltd. Ya'an, 625000, China;
- 3) College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China;
- 4) College of Mechanical and Electrical Engineering, Hainan Institute of Science and Technology, Haikou 571126, China)

This paper is analyses the development of the trial of digging-pulling style cassava harvester.

### D. Performance of an improved manual cassava harvesting tool as influenced by planting position and cassava variety

Author name: Shadrack Kwadwo Amponsah\*, Joseph Nketiah Berchie, Joseph Manu-Aduening, Eric Owusu Danquah, Jonas Osei Adu, Adelaide Agyeman and Enoch Bessah

CSIR - Crops Research Institute, Kumasi, Ghana.

This paper is analyses the performance of an improved manual cassava harvesting tool as influenced by planting position and cassava variety. It is determine among four varieties, the cassava variety that best facilitates manual harvesting. It is required the force of cassava harvesting under different planting positions is calculated.

#### E. Forces Required to Vertically Uproot Tree Stumps.

Author name:Ola Lindroos, Marina Henningson, Dimitris Athanassiadis and Tomas Nordfjell.

This paper is analyses by the vertically uprooting the tree stumps with using forces. The main objective of this study was to quantify the force required to vertically uproot stumps in one piece in order to identify possible adaptations of current machinery, or facilitate the development of new machinery, for efficient uprooting.

### III. MANUAL HARVESTING METHOD

The cassava harvesting is mostly done manually. The stems of the cassava plants are first cut off leaving the stumps with the tubers in the ground. The stumps are pulled manually by hand and the tubers gets lifted out from the ground. The tubers are then separated from the stumps and collected. Later farmers used digging instruments to reap cassava. The instruments or devices work on the techniques of 'grasp' and lift. The cassava thus harvested are gathered in gunny bags and sent to production units.

### IV. CONSTRUCTION



The frame of the machine is first constructed using cast iron angle size to house the engine, shafts to which wheels are attached and also the chain mechanism for lifting tubers. The engine is mounted on the rear side of the frame. Wheels are fixed to shafts joined to the frames. The back wheel shaft has a sprocket wheel at the Centre for power transmission by chains drive from engine. For the construction of the chain mechanism used for uprooting, a shaft at a height of 2 feet above the back wheel shaft is fixed. This shaft contains 2 sprocket wheels and 2 pinion wheels. To each of the 2 pinion wheels 2 bevel gears are meshed which in drives 2 bigger sprocket wheels which drives the chain. The bevel gears and the bigger sprocket wheels are supported by a separate frame. The frame is front of the front wheel shafts supports 2 smaller

sprocket wheels, 2 chains are driven by these sprocket wheels and the bugged sprocket wheels mounted on the frame 2 feet above the back wheel shaft 2 shovel blades are welded to the front frame to loosen soil surrounding the tubers.

### V. WORKING

The engine power is transmitted to the back wheel shaft through the chain and sprocket arrangement. This peoples the machine forward as all the 4 wheels turn. As the back wheel shaft rotates, the rotary motion is transmitted to the shaft fixed 2 feet above it through the sprocket wheels and chain drive. Both the shafts rotate at same speed. This rotary motion is transmitted to the 2 bigger sprockets arranged horizontally through the bevel gear and pinion arrangement. The 2 bigger sprocket wheels rotate in opposite directions. As the sprocket wheels rotate in opposite direction, the chain between these 2 sprocket wheels and the smaller sprocket wheels mounted at the front of the machine. As the machine moves forward by the engine power, the shovel blades in front of the machine loosens the soil around the tubers. The stump of the cassava plant gets caught between the 2 chains and gets pulled out of the ground by the chain movement. The tubers are lifted up, carried by the chain and gets dropped off into the tray as the chains separate at the bigger sprocket wheel end the tubers from the tray are then collected into gunny bags.



#### A. Design calculation

##### 1) Bevel Gear:

##### 1) 1. Gear ratio:

$$i = N_1 / N_2 = 4500 / 1500 = 3$$

pitch angle: for right angle bevel gear,  $\tan \delta_2 = I = 3$  or  $\delta_2 = \tan^{-1}(3) = 71.56^\circ$

$$\text{and } \delta_1 = 90 - \delta_2 = 18.43^\circ$$

##### 2) Material for pinion and gear:

Cast iron grade 35 heat treated

$$\sigma_u = 350 \text{ N/mm}^2$$

(Refer the From PSG pg no : 1.40)

$$3) \text{ Gear life in hours } = N = 10,000 \times 4500 \times 60 = 270 \times 10^7 \text{ cycles}$$

##### 4) Calculation of initial design torque:

We know that,  $[M_t] = M_t \times K \times K_d$

$$M_t = 60 \times 2700 / 2\pi \times 4500$$

$$M_t = 5.72$$

$$K \cdot K_d = 1.3 \text{ (as per assumption)}$$

$$[M_t] = 5.72 \times 1.3 = 7.44 \text{ N-m}$$

5) Calculation of  $E_{eq}$ ,  $[\sigma_b]$ ,  $[\sigma_c]$ :

To find  $E_{eq}$ :  $E_{eq} = 1.4 \times 10^5 \text{ N/mm}^2$  for cast iron,  $\sigma_u > 280 \text{ N/mm}^2$

To find  $[\sigma_b]$  = for rotation in one direction

(Refer the From PSG pg no: 8.20)

$$= 0.8852, \text{ for CI}$$

$$K_\sigma = 1.2;$$

(Refer the From PSG pg no: 8.19)

$$n = 2,$$

$$\sigma_{-1} = 0.45 \sigma_u$$

$$\sigma_u = 350 \text{ N/mm}^2$$

$$\sigma_{-1} = 0.45 \times 350 = 157.5 \text{ N/mm}^2$$

$$\text{Then } [\sigma_b] = (1.4 \times 0.8852 \times 157.2 / (2 \times 1.2)) = 81.33 \text{ N/mm}^2$$

To find  $[\sigma_c]$ :

$$[\sigma_c] = C_b \times HB \times K_{cl}$$

$$C_b = 2.3 \text{ (Refer the From PSG pg no: 8.16)}$$

$$HB = 200 \text{ to } 260$$

$$K_{cl} = \sqrt[6]{10^7/N}$$

$$= 0.393, \text{ for CI}$$

$$[\sigma_c] = 2.3 \times 260 \times 0.833 = 498.08 \text{ N/mm}^2$$

6) Calculation of cone distance (R):

We know that

$$R \geq \psi y \left( \sqrt{(i^2 + 1)} \right) \left\{ \sqrt[3]{ \left[ \frac{0.72}{\psi y - 0.5[\sigma_c]} \right]^2 \times E_{eq} \frac{[M_t]}{i} } \right\}$$

$$\psi y = \frac{R}{b} = 3$$

$$R \geq 50.2$$

$$R = 51 \text{ mm}$$

7) Assume  $Z_1 = 20$ , Then  $Z_2 = I \times Z_1 = 2 \times 20 = 40$

Virtual number of teeth  $Z_{v1} = Z_1 / \cos \delta_1 = 20 / (\cos 26.57^\circ) = 23$

And  $Z_{v2} = Z_2 / \cos \delta_2 = 40 / (\cos 63.43^\circ) = 90$

8) Calculating the transverse module (mt):

$$= 2.28 \text{ mm take as } 2.5$$

(Refer the From PSG pg no :8.2)

9) Revision of cone distance R:

We know that,

$$R = (0.5 Mt \sqrt{Z_1^2 + Z_2^2}) = 0.5 \times 2.5 \sqrt{(20^2 + 40^2)} = 55.9 \text{ mm}$$

10) Calculation of b,  $M_{av}$ ,  $d_{1av}$ , v, and  $\psi y$ :

$$\text{Face width (b); } b = R / \psi y = 55.9 / 3 = 18.63 \text{ mm}$$

$$\text{Average module (m}_{av}\text{): } m_t - (b \sin \delta_1 / Z_1) = 2.0863 \text{ mm}$$

$$\text{Average pcd of pinion (d}_{1av}\text{)} = d_{1av} = m_{av} \times Z_1 = 2.083 \times 20 = 41.66 \text{ m}$$

$$\text{Pitch line velocity v: } = 1.745 \text{ m/s}$$

$$\psi y = b / d_{1av} = 18.63 / 41.66 = 0.477$$

11) IS quality bevel gear is assumed (Refer the From PSG pg no: 8.3)

12) Revision of design torque  $[M_t]$

We know that  $[M_t] = M_t \times K \times K_d$

$$K = 1.1 \text{ for } b / d_{1av} \leq 1, \text{ (Refer the From PSG pg no: 8.15)}$$

$$K_d = 1.35 \text{ P SG 8.16}$$

$$[M_t] = 22.38 \times 1.1 \times 1.35 = 33.24 \text{ N-m}$$

13) Check for bending stress

We know that the induced bending stress

$$\sigma_b = \left( \frac{R \sqrt{(i^2 + 1)} [M_t]}{(R - 0.5b)^2 x b x m_t x Y_{v1}} \right)$$

Where  $Y_{v1} = 0.408$  for  $Z_{v1} = 23$ , (Refer the from PSG pg no: 8.18)

$$\sigma_b = 100.75 \text{ N/mm}^2$$

Which is not satisfactory

Recalculate with various b,  $d_{av}$ , v,  $\psi y$ ,  $m_{av}$ ,

14) Check for wear strength: We know that the induced contact stress,

$$\sigma_c = \left( \frac{0.72}{R - 0.5b} \right) \left( \left( \frac{\sqrt{(i^2 + 1)^3}}{(i \times b)} \right) \times E_{eq} [M_t] \right)^{\frac{1}{2}}$$

$$= 183.55 \text{ N/mm}^2.$$

We find that  $\sigma_c < [\sigma_c]$ , thus the design is safety.

B. Chain

$$\text{Power (p)} = 2.7 \text{ kw}$$

$$\text{Motor speed} = 4500 \text{ rpm}$$

$$\text{Compressor speed} = 4000 \text{ rpm}$$

$$\text{Centre distance (a)} = 30 \text{ mm}$$

STEP 1: selection of number of teeth on the pinion (Refer the PSG pg.no: 7.74)

Recommended  $z_1$ , for  $i = 2-3$

$$\text{No. of teeth on the sprocket } z_1 = 25$$

STEP 2: selection of number of teeth on the sprocket (Refer the PSG pg no: 7.74)

$$Z_1 = z_1 \times i$$

$$= 2.94 \times 25 = 75$$

STEP 3: optimum centre distance. (Refer the P.S.G pg.no: 7.74)

$$a = (30 \text{ to } 50) p$$

If 30 is used

$$P_{\max} = 500/30 = 16.66$$

$$P_{\min} = 500/50 = 10$$

always select larger pitch value

standard pitch is 15.875 is chosen (Refer the PSG pg.no: 7.74)

$$\text{pitch } p = 15.875$$

STEP 4: selection of chain (Refer the PSG pg.no: 7.74)

Assume the chain to be duplex.

The chosen chain number is 10A-2/DR50

STEP 5: Total load on the driving side of the chain (Refer the P.S.G pg no: 7.78)

$$P_t = P_t + P_c + P_s$$

$$P_t = 1020 \text{ N/mm}$$

(tangential force due to power transmission)

$$v = \text{no of teeth on the sprocket} \times \text{pitch} \times \text{speed} / 60$$

$$= 25 \times 15.875 \times 970 / 60$$

$$v = 6416.14 \text{ mm/s} = 6.42 \text{ m/s}$$

$$P_t = 1020 \times 11 / 6.42$$

$$= 1747.66 \text{ N}$$

w.k.t  $P_c = mv^2/g$  (centrifugal tension) (Refer the PSG pg.no: 7.78)

for mass m to be found for selected during fine mass per unit length

$$(1.78 \times 10 / 10)$$

$$m = 1.78$$

$$P_c = 1.78 \times 6.4162^2 = 73.273 \text{ N}$$

w.k.t  $P_s = k \cdot W \cdot a$  (Refer the PSG pg.no: 7.78)

Assuming horizontal position  $k = 6$ ,  $W = 1.78 \times 10 = 17.8 \text{ N/m}$ ,

$$a = 500 \text{ mm}$$

$$P_s = 6 \times 17.8 \times 5 = 53.4 \text{ N}$$

$$P_t = 1747.66 + 73.273 + 53.4 = 1874.33 \text{ N}$$

STEP 6: service factor (ks) (Refer the PSG pg.no: 7.76 to 7.77)

$$K_s = k_1 \times k_2 \times k_3 \times k_4 \times k_5 \times k_6$$

$$K_1 = 1 \text{ (load factor)}$$

$$K_2 \text{ (factor for distance regulation)} = 1.25 \text{ assuming centre distance}$$

$$K_3 \text{ (factor for centre distance of sprocket)} = 1 \text{ for (30 to 50) p}$$

$$K_4 \text{ (factor for the position of sprocket)} = 1$$

$$K_5 \text{ (lubrication factor)} = 1.5$$

$$k_6 \text{ (rating factor)} = 1.25$$

$$k_s = 1 \times 1.25 \times 1 \times 1 \times 1.5 \times 1.25 = 2.343$$

STEP 6: Design load (Refer the From PSG pg.no: 7.72)

$$\text{Design load} = pt \times k_s = 1875.423 \times 2.343 = 4394.116 \text{ N}$$

$$Q = 4440 \times 10 = 44400$$

$$\text{Actual factor of safety} = 44400$$

$$4394.116$$

$$= 10.10$$

Recommended FOS is obtained (Refer the From P.S.G pg.no: 7.77)

The recommended FOS for the speed of rotation of small sprocket for

330rpm is 8.55

The actual FOS > recommended FOS

So the design is safe

### C. Sprocket

#### 1) Pitch circle diameter:

The tooth form of a sprocket is derived from the geometric path described by the chain roller as it moves through the pitch line, and pitch circle for a given sprocket and chain pitch.

$$d = p / \sin(\tau/2)$$

$$P=1, \tau=.39$$

$$= 1 / \sin (.39/2)$$

$$= 1/0.193$$

$$d = 5.181 \text{ cm}$$

#### 2) Root circle diameter

Root Diameter (R.D.) is the diameter of a circle around the bottom (root) of the gear tooth spaces.

$$D_f = d - d_1$$

$$D = 7.5, d_1 = 3$$

$$= 7.5 - 0.3$$

$$D_f = 7.2 \text{ cm}$$

$$3) \text{ Tooth radius: } = 0.505 * d_1 + 0.0693 \sqrt{d_1}$$

$$D_1 = 0.3$$

$$= (0.505 * 0.3) + 0.0693 \sqrt{0.3}$$

$$R_{1 \text{ max}} = 0.1976 \text{ cm}$$

$$R_{1 \text{ min}} = 0.505 * d_1$$

$$= 0.505 * 0.3$$

$$R_{1 \text{ min}} = 0.1515 \text{ cm}$$

$$R_{1 \text{ min}} = (0.008d_1) (z+180)$$

$$D_1 = 0.3, z = 18$$

$$= (0.008 * 0.3) (182 + 180)$$

$$R_{2 \text{ max}} = 1.2096 \text{ cm}$$

$$R_{2 \text{ min}} = 0.12d_1 (z+2)$$

$$D_1 = 0.3, z = 1$$

$$= (0.12 * 0.3) (18 + 2)$$

$$R_{2 \text{ min}} = 0.72 \text{ cm}$$

#### 4) Top diameter:

$$D_{a \text{ max}} = (d + 1.25p) - d_1$$

$$D_1 = 0.3, D = 7.5$$

$$= (7.5 + 1.25 * 1) - 0.3$$

$$D_{a \text{ max}} = 8.45 \text{ cm}$$

$$D_{a \text{ min}} = d + [1 - (1.6/z)] * p - d_1$$

$$= 7.5 + [1 - (1.6/18)] * 1 - 0.3$$

$$D_{a \text{ min}} = 8.112 \text{ cm}$$

#### 5) Tooth height:

$$K_{\text{max}} = (0.625 * p) - (0.5d_1) + (0.8/z) * p$$

$$P = 1, d_1 = 0.3, z = 18$$

$$= (0.625 * 1) - (0.5 * 0.3) + (0.8/18) * 1$$

$$K_{\text{max}} = 0.519 \text{ cm}$$

$$K_{\text{min}} = 0.5 * (p - d_1)$$

$$= 0.5 * (1 - 0.3)$$

$$K_{\text{min}} = 0.35 \text{ cm}$$

#### 6) Velocity:

$$V_{\text{max}} = (d/2) * \omega = (p * n) / (19100 * \sin(180/z))$$

$$P = 1, n = 1725, z = 18$$

$$= (1 * 1725) / (19100 * \sin(180/18))$$

$$= 1725 / 2476.012$$

$$V_{\text{max}} = 0.696 \text{ cm/sec}$$

$$V_{\text{min}} = (d * n / 2) * \omega = (p * n) / (19100 * \tan(180/z))$$

$$= (1725 * 1) / (19100 * \tan(0.174))$$

$$V_{\text{min}} = 0.513 \text{ cm/sec.}$$

### D. Advantages

- 1) Man power is less.
- 2) Saves time.
- 3) Easy way of uprooting cassava.
- 4) High productivity and quality.

## VI. CONCLUSION

The machine has been designed to make its operation easier and efficient. The cassava harvester runs smoothly and lifts the cassava to upward. The machine requires less human energy and the movement of the mechanisms is relatively smooth. Utilization of this machine is for better than manual harvesting since it saves time, the cost of harvesting is reduced, and it is faster. This machine can be further developed by using biofuels for energy.

## REFERENCES

- [1] A.S. Akinwonmi and F. Andoh Department of Mechanical Engineering, University of Mines and Technology, Tarkwa, Ghana. Design of a cassava uprooting device, June 8, 2012.
- [2] Shadrack Kwadwo Amponsah<sup>1</sup>, J. Thajudhin Sheriff<sup>2</sup>, Gangadharan Byju<sup>2</sup>, CSIR-Crops Research Institute, Kumasi, Ghana; 2. ICAR- Central Tuber Crops Research Institute, Sreekariyam, India), Comparative evaluation of manual cassava harvesting techniques in Kerala, India.
- [3] Liao Yulan<sup>1</sup>, Sun Youpan<sup>2</sup>, Liu Shihao<sup>3</sup>, Cheng Danping<sup>4</sup>, Wang Gaoping<sup>1</sup>
- [4] (1. College of Mechanical and Electrical Engineering, Hainan University, Haikou 570228, China;
- [5] Jian'an Branch, China Changan Automobile Group Co., Ltd. Ya'an, 625000, China;
- [6] College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China, Development and prototype trial of digging-pulling style cassava harvester.'

- [7] Shadrack Kwadwo Amponsah\*, Joseph Nketiah Berchie, Joseph Manu-Aduening, Eric Owusu Danquah, Jonas Osei Adu, Adelaide Agyeman and Enoch Bessah CSIR - Crops Research Institute, Kumasi, Ghana, Performance of an improved manual cassava harvesting tool as influenced by planting position and cassava variety.
- [8] Ola Lindroos, Marina Henningsson, Dimitris Athanassiadis and Tomas Nordfjell, Forces Required to Vertically Uproot Tree Stumps.

