Design, Development and fabrication of Multi Crop Cutter Powered by Electric Motor


[1][2][3][4][5] Student of B.E. Mechanical, G.H.Raisoni C.O.E.M., Chas, Ahmednagar

Abstract

This machine targets the small scale farmers who have land area of less than 2 acres. This machine is compact and can cut up to two rows of wheat crops. It has cutting blades which cut the crop in a scissoring type of motion. It runs on Electric motor of 1HP, this power from motor, is provided through pulley and gear box arrangement to the cutter. A collecting mechanism is provided for the collection of crops to one side after cutting. This mechanism is powered by pulley arrangement. This compact harvester is manufactured using locally available spare parts and thus, it is easily maintainable. This harvester might be the solution to the problems faced by a small scale farmer regarding cost and labour implementation. After testing this machine in farm it is found that the cost of harvesting using this harvester is considerably less as compare to manual harvesting.

Keywords: productivity, Crop cutting, harvester, reaper, scissoring action, Fabrication etc

1. INTRODUCTION

Recently ruler has seen a shortage of skilled labour available for agriculture. Because of this shortage the farmers have transitioned to using harvesters. These harvesters are available for purchase but they are not affordable because of their high costs, however, agriculture groups make these available for rent on an hourly basis. But the small holding farm owners i.e. generally having land less than 2 Acers generally do not require the full-featured combine harvesters. Due to financial or transportation reasons these combine harvesters are not available in all parts of rural area. Thus, there is a need for a smaller and efficient combine harvester which would be considerably cheaper and also more accessible. The mission is to create a portable, low cost mini harvester and user-friendly. These problems gave us the basic idea about what was required in the current situation. The idea was to create a machine which will reduce the labour required to harvest crops and which is cheap. This machine has the capability and the economic value for fulfilling the needs of farmers having small land holdings which is less than 2 acres. This machine is cost effective and also easy to maintain and repair for farmers.

1.1 Objectives

- The objective of this project is to design and fabricate a low cost multi crop cutting machine based on the need of farmers.
- To minimize time of harvesting
- To minimize the human effort.

2. Present State Of The Art of Multi Crop Cutting Process and Their Shortcomings

2.1 The present state of art of multicrop cutter described below

There are two ways of crop cutting process
1. Manual process or with help of sickle.
2. Mechanized motor process.

In a manual process the crop cutting is done with the blade hampering on the crop or sack containing the crop or with the help of rotary equipment which is very tedious work. Which is cut the crop. Whilst in the motorized process the motor used in this process for to cut the crop with the help of cutter blade to cut the crop .the power transfer and power done with the help of motor through suitable mechanism. If one carefully observes the first process then he could find the following limitations which are given below

1.This process renders fatigue to the hand; it produces damages to the hands
2.As it is continuous process it requires monotonous work.
3.It is time consuming and laborious process so no one wants to do in today era.On the other side, in the second process following limitations have been found out which are discussed below,
4. The requirement of electricity is prerequisite for this process. As today’s main problem is the power crises and load shading and the machine becomes idle in that case.

5. The cost of the machine is quite high and the rural people could not afford it to buy.

2.2 Proposed Solution Over The Present State Of Art

A proposed solution over the present state of art is being explained through this article. A solution is the evolution of the unique machine, which would run with the help of human power. A schematic diagram is shown in the figure 2.1.

It is a walk behind type of harvester which is powered by the 0.75Kwatt, 1400 rpm electric motor. With the help of V-belt, drive power is transmitted to gearbox. As the required rpm at cutter is as less as 100 rpm, a spur gearbox and a bevel gearbox is used. Here bevel gear is used to change the direction of drive in the gear system by 90°. One end of this output shaft is connected to slider crank mechanism which converts rotary motion of shaft into reciprocating motion of cutter blade. Reciprocating cutter blade slides over fixed blade and creates scissoring action responsible for cutting the crops. Collecting mechanism consist of flat belt with collecting plates bolted on it. Collecting belt simply carry and cut crop sideways.

Fig.2.1 Cad model

2.3 An Approach to Develop The Crop cutting electric motor

A proposed machine can be developed by using following procedure.

Firstly the cutting strength of different crops will be estimated by performing test on apparatus, which is made especially for this work. The estimated thre cutting force will be used for finding the cutting force. The weight of the process unit the kinematic entities of different links the reaction force offered due to cutting force will be use for the estimation of load torque, in fact this load torque becomes useful for the estimation of demand power. This demand power will be useful in to ascertain the dimension of various components associated with the machine by obtaining design dimensions of components’ fabrication will be done at last trials will be taken to ascertain viability.

3. DESIGN CALCULATIONS

3.1 Power of electric motor

\[ P_i = \frac{(V \times I \times P.F \times \sqrt{3})}{1000} \]

Where,
\( P_i \) = single phase power, Kw
\( V \) = Voltage, volts
\( I \) = Current, amp
\( P.F \) = Power factor
\[ P_i = \frac{(240 \times 2.4 \times 0.76 \times \sqrt{3})}{1000} \]
\[ P_i = 0.75Kw \text{ Or } 1.0053 = 1hp \]

ii) Input Power at full load

\[ P_a = H.P \times (0.7457/\eta_{in}) \]
Where,
\( P_{ir} \) = input power at full load, kw
\( H.P \) = Horse power
\( \eta_m \) = efficiency of motor
\( P_{ir} = 1 \times (0.7457/58) \)
\( P_{ir} = 0.01928 \) kw

**Design Of Spur Gear**

*In the present case,*

Rated power = 1hp

Speed of the gear (pinion), \( N_p = 1440 \) rpm

Teeth of gear, \( T_p = 68 \)

\( V.R. = 1.02, V.R. = \frac{N_p}{N_{p_0}} \cdot 1.02 = \frac{N_p}{185,5} \)

\( N_{p_0} = 189.21, \) Approx \( 190 \) rpm

\( N_p \ast T_p = N_{p_0} \ast T_{p_0} \)

\( T_{p_0} = 85 \)

**3.1.1. Design power (Pd):**

\( P_d = P_R \ast K_L \)

\( = 0.50 \ast 180 = 1 \) hp = 746 watt

Toothload, \( F_t = \frac{P_d}{V_p} \)

\( V_p = \frac{\pi N_p T_p}{60 \ast 10^3} = 1.432 \) m/s

**3.1.2. Bending strength \( F_b \)**

\( F_b = S_b \ast C_y \ast b \ast Y \ast m \)

\( S_b = 70 \) cast iron medium grade

\( C_y = 0.4 \)

\( Y = 0.485 \)

\( Y_p = 0.940 \ast Y_g = 0.421 \)

\( \ast Y_y = 70 \ast 0.340 = 23.8 \)

\( S_b \ast Y_b = 70 \ast 0.421 = 29.47 \)

Select the maximum value

\( F_b = 140 \ast 0.340 \ast 10 \ast m \ast m = 476 m^2 \) N

Now find module

\( F_d = F_t \)

\( 4760 m^2 = \frac{\pi N_p T_p}{60 \ast 10^3} m = 1.88 \)

Calculate actual value

\( F_t = \frac{140}{0.276} = 1300 \) N
PCD of pinion

\[ D_p = m \cdot T_p = 2 \cdot 19 = 38 \text{ mm} \]
\[ D_p = m \cdot T_p = 2 \cdot 68 = 136 \text{ mm} \]
\[ V_p = 0.278 \cdot m = 0.278 \cdot 2 = 0.574 \text{ m/s} \]

Calculate the face of width b minimum

\[ F_b = S_b \cdot C_d \cdot b \cdot Y \cdot m \ldots \ldots \ldots \text{Assume class 1} \]
\[ C_p = \frac{1}{(2 + V_p)} = 0.5454 \]
\[ F_b = 30 \cdot 3 \cdot 0.5454 \cdot b_{min} \text{ N} = 49 \cdot b_{min} \text{ N} \]

Equating
\[ F_b = F_t \]
\[ 49 \cdot b_{PDC} = 894 \]
\[ b_{min} = 18.24 \text{ mm} \]
\[ b_{extra} = 18.24 \cdot 3 = 54.7 \text{ mm} \]
\[ F_b = 894.52 \]

Dynamic load, \( F_d \)

\[ F_d = F_t + \left[ \frac{21V_p \cdot C_d \cdot b + F_b}{21V_p \cdot \sqrt{C_d \cdot b + F_b}} \right] \]

\[ C = 11400 \text{e (100 full depth)} \]

\[ F_d = 3760N \]

\[ F_d \geq F_b \ldots \ldots \ldots \ldots \text{Hence design is safe.} \]

Limiting wear strength, \( F_w \)

\[ F_w = D_p \cdot b \cdot Q \cdot k \]
\[ Q = \left[ \frac{5r_d}{i \cdot V_p} \right] = 1.56 \]
\[ F_w = 38 \cdot 20 \cdot 1.56 \cdot k = 1185 \text{ k N} \]
\[ F_w = F_d \]

1185*k=3760

K= 3.17

\[ S_{ad} = 0.42 \]

(BHN)p = 150

(BHN)g = 180

= 4950*0.4255

= 2106.225

\[ F_w \geq F_d \]

Hence design is safe.

3.3 Design Of Antifriction Bearing
There are two antifriction bearings B1 and B2 used in the experimental setup. The maximum reaction developed at bearing B2, i.e., \( F_{r2} = 667.33 \text{ N} \), is considered for designing the bearing.

1. Equivalent load coming on bearing, \( F_e, \text{ N} \)

\[
F_e = (X F_r + Y F_a) K_s K_o K_p K_r
\]

\[
F_r = 750 \text{ N}
\]

\[
F_a = 0 \text{ N}
\]

\[
e = F_a / F_r
\]

\[
e = 0
\]

Selecting self aligning ball bearing

\[
X = 1, \quad Y = 2.3
\]

\[
K_p = 1 \text{ (no preloaded bearing)}
\]

\[
K_r = 1 \text{ (outer race fixed, inner race rotating)}
\]

\[
K_s = 2 \text{ (moderate shock load)}
\]

\[
F_e = (X F_r + Y F_a) K_s K_o K_p K_r
\]

\[
= (1 \times 750 + 0) \times 1 \times 1 \times 1 \times 2
\]

\[
= 1334.66 \text{ N}
\]

2. Life of bearing, \( L \) (million revolution)

\[
L = \left(\frac{C}{F_e}\right)^n \text{ Kret.}
\]

\[
L = 500 \text{ (demonstration model)}
\]

\[
n = 3 \text{ for ball bearing}
\]

\[
Kret = 1 \text{ (reliability = 90\%)}
\]

\[
C = (500)^{(1/3)} \times F_e
\]

\[
C = 10818.138 \text{ N}
\]

Selecting series 02xx (C = 11000)

Dimension \( d = 25 \text{ mm} \),

\[
D = 52 \text{ mm}
\]

\[
B = 15 \text{ mm}
\]

3.4 Design of Handle

A square steel pipe used as a handle which is folded to a length of 2.74 m and 0.76 m orientation toward the machine frame at an angle of 45 degree which is welded for the operator’s convenience. The handle is subjected to both axial and bending forces due to the inclined position.

4. Construction And Working

Construction and fabrication of multi crop cutter machine

The fabrication of any machine demands adequate planning and selection of systematic process. Basically, the fabrication is carried out after the design process. Once the required dimension obtained then the only work remains and that is to convert the drawing dimensions into real physical model. The forthcoming article focuses on how the design is obtained in previous chapter being converted in real physical model.

4.1 Mechanical Parts Of The Machine


4.2 Designed Model Of multicrop cutter by using electric motor

As per the designed and analytical calculations made in the previous chapter following CAD model is developed by using different commands of Pro E software. This CAD software provides the tools needed to perform modeling of different parts of the proposed machine efficiently and free from tedious and time consuming task. The front view and side view of the model is shown below.
4.3 Fabrication

The manufacturing process used in the fabrication of multicrop cutter machine is such that the total cost of fabrication is low and also one that can make use of the available materials. The manufacturing process involved in this work includes, joining of metal parts by welding, cutting using hacksaw and hand cutting machine. Each component of the machine is fabricated separately before they are joined or welded together as the case may be.

4.4 WORKING

It is a walk behind type of harvester which is powered by the 1 HP, 1440 rpm electric motor. With the help of V-belt, drive power is transmitted to gearbox. As the required rpm at cutter is as less as 200 rpm, a spur gearbox used. Here high torque Johnson type motor is used to collecting the crop cut by cutter blade. One end of this output shaft is connected to slider crank mechanism which converts rotary motion of shaft into reciprocating motion of cutter blade. Reciprocating cutter blade slides over fixed blade and creates scissoring action responsible for cutting the crops. Collecting mechanism consist of flat belt with collecting plates bolted on it.
5. COST ESTIMATION

Actual cost of crop cutter Machine

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Part Required</th>
<th>Quantity</th>
<th>Price/part (Rs.)</th>
<th>Total cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electric motor</td>
<td>1</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>2</td>
<td>Spur gear box</td>
<td>1</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>6” pulley x2</td>
<td>1</td>
<td>542</td>
<td>542</td>
</tr>
<tr>
<td>4</td>
<td>Bearing</td>
<td>2</td>
<td>192</td>
<td>500</td>
</tr>
<tr>
<td>5</td>
<td>Shaft</td>
<td>1</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>Wheel assembly</td>
<td>1</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>7</td>
<td>52” V belt</td>
<td>1</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>8</td>
<td>32” V belt</td>
<td>1</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>9</td>
<td>Frame Angle 40x40x5 mm</td>
<td>37 kg</td>
<td>54/kg</td>
<td>1500</td>
</tr>
<tr>
<td>10</td>
<td>MS plate 16mm,10mm</td>
<td>13 kg</td>
<td>58/kg</td>
<td>750</td>
</tr>
<tr>
<td>11</td>
<td>1”dia -Pipe</td>
<td>2</td>
<td>325</td>
<td>650</td>
</tr>
<tr>
<td>12</td>
<td>G.I. Sheet</td>
<td>1</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>13</td>
<td>Collecting belt</td>
<td>1</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>14</td>
<td>Bearing circles</td>
<td>10</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>15</td>
<td>Cutter blade</td>
<td>18</td>
<td>40</td>
<td>720</td>
</tr>
<tr>
<td>16</td>
<td>Nut bolts etc</td>
<td></td>
<td>113</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Labour charge</td>
<td></td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Electricity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>VAT charges</td>
<td></td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total cost (Rs)</td>
<td></td>
<td>14600</td>
<td></td>
</tr>
</tbody>
</table>

6. Testing And Results

After fabrication of machine we did experimental analysis, we conduct the four major tests they are
1. Grass cutting test
2. Testing of wheat cutting

6.1 Test results on Grass Cutting

This design was tested against standard manual cutting on a farm. Tests were performed cutting a 10 m long sugarcane row. With each test,
(1) The time taken to cut the row,
(2) The amount of cane left behind (butt height) and
(3) The stalk damage at the impact zone were recorded. Stalk damage was subjectively assessed using a damage classification developed. This classification scores a zero for a very clean cut and an eight for an extensively damaged stalk. Each test was repeated at least eight times, allowing for the calculation of means and standard deviations. It should also be noted that manual cane cutting was performed by inexperienced persons, and improved performances may be expected among experienced labourers. The brush-cutter was found to be easy to use, even with no previous experience in cane cutting, and although not tested, it is believed that it could be used on steep slopes. Various safety measures, such as protective clothing, glasses, ear covers and a blade cover were required to safeguard the brush-cutter operator.

6.2 Test results for the wheat Harvesting

A. Comparison of Harvesting Cost by Traditional Method and Our Harvester:
1) Harvesting done by manual process:
Amount paid to the labour for one day = Rs. 250 per labour
Total number of labour required in general to harvest the 1 acre farm of wheat in a day = 6
Total amount paid to the labour = 6 x 250
= Rs. 1500 per acre in one day
Therefore, total expenditure in one day is = Rs. 1500

2) Harvesting done by machine:
Quantity of electricity for 0.25 to 0.5 acre = Required 2 hours
= 746*2/1000
= 1.5 unit electricity required
1 unit = 7 Rs
Hence 1.5 unit = 1.5*7 = 11 Rs

Quantity of Electricity require for 1 to 1.2 acre = Required 4-5 hours
= 746*5/1000
= 3.73 unit electricity required
1 unit = 7 Rs
Hence 1.5 unit = 3.73*7 = 26.11 Rs

Cost of Electricity per unit = 7 Rs.

Design, Development and Fabrication of a Compact Harvester

Total cost of Electricity for 1 acre farm for a day = 27 Rs
Amount paid to the labour = 250 Rs
Total expenditure = Total cost of electricity + Amount paid to the labour + Maintenance
= 27+250+50
= 327 Rs

Amount saved by using the harvester = 1500 – 327 = 1173 Rs. per day per acre.

7. CONCLUSION

Based on the present works the following are some important conclusions have been done.

1. From this work the following conclusions were drawn For the work to be accomplished in 1 acre area without a machine (crop cutter) or manually, it costs Rs:4200/- by a minimum of Rs:350/- per each labour in a day. Whereas, by using an Multi crop cutter we can accomplish the same work in the same area (1 acre) with only one labour (skilled labour), it takes 5-6 hours at a cost of only Rs:650/- (i.e., fuel Rs:300/- & labour cost 350/-). So by using an ultraportable crop cutter we can reduce the cost up to 80%. The performance through manual cutting cannot be the same throughout the day, as man get strained whereas a machine cannot Therefore, 80% of the time can also be saved by using the Multi crop cutter. It is concluded that the device is most economical.

2. The Combined reaper and collector machine is built to be compact and efficient to cut the crops. The machine was tested on a field to check its cutting capability and efficiency.

3. The harvesters available in market are suitable for large farms, so this can be the best machine for the farmers with small land. The success of this machine depends on how the farmers receive this machine as their ally.

4. There are some changes that need to be done on the machine and a final product is to be taken out for sell.

5. From this work the following conclusions were drawn for the work to be in 1 acre area without a multi crop cutter or manually, whereas by using a multi crop cutter we can complete the same work in the same area (1 acre) with only one labor. The samethroughout the day, as man get strained, whereas a machine cannot.

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BIOGRAPHIES

“Vilas S. Gadhave studying in B.E. Mechanical, G.H RaisoniCOEM, chas, Ahmednagar, Maharashtra, India”

“Pravin P. Gadsing studying in B.E. Mechanical, G.H RaisoniCOEM, chas, Ahmednagar, Maharashtra, India”

“Y.K. DIKE studying in B.E. Mechanical, G.H RaisoniCOEM, chas, Ahmednagar, Maharashtra, India”

“A.S. JAYBHAYE studying in B.E. Mechanical, G.H RaisoniCOEM, chas, Ahmednagar, Maharashtra, India”

“P.A. LONDHE studying in B.E. Mechanical, G.H RaisoniCOEM, chas, Ahmednagar, Maharashtra, India”

Prof. Praveen Kiran Mali is working in GHRCOEM Savitribai Phule Pune University. He has completed M.Tech in Mechanical Design. He has published 14 research papers in various international journals and also published the book “Design of machine elements by using maize thresher” in Lambert academic publishing Germany recently. He is member of professional bodies like ISTE, IAE, etc. He has also work experience in automobile industry about instrument cluster, fuel level sensor, etc. and design fixture for mahindramahindra cluster.