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MODIFICATION OF A COCONUT DE-HUSKING MACHINE

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ABSTRACT

Contrary to the immense economic importance of coconut for both industrial and domestic uses, de-husking of the fruits after harvesting constitutes the most difficult and dangerous operations during processing. Modification of a manually operated coconut de-husking machine was carried out. The machine was designed and fabricated using locally sourced materials. It consists of the supporting frame where the machine components were mounted. The de-husking unit consists of two steel pipe rollers with spikes and shafts. The driving and driven roller shafts are mild steel rods supported at both ends by ball bearings. Two spur gears were used with the same pitch circle diameters and number of teeth respectively. Flywheel was also incorporated to produce high torque. When the handle is rotated, power is transmitted through the gearing arrangement to the rollers with plurality of spikes and rotate them in opposite directions toward the centre thereby causing both the gripping and tearing of the husk when the coconut is placed in between the rollers. Different sizes of coconut fruits were loaded at different times on the machine and the time taken for each fruit to be de-husked was recorded. A total of 20 fresh nuts were tested. The performance evaluation shows that the average efficiency of the machine was 85% while the average capacity is 65 coconuts per hour which is higher compared to the existing coconut de-husking machine. On the other hand, the percentage number of distorted coconuts was 10% which is lower compared to the existing coconut de-husking machine. Hence it is recommended for use by farmers.

Keywords: Coconut, De-husking, Performance evaluation, Machine

INTRODUCTION

Coconut (Cocos nucifera) is one of the most world's useful and important perennial plants. An individual coconut fruit is made up of an outer exocarp, a thick fibrous fruit coat known as husk, the hard protective endocarp or shell called "eyes" are at one end of the nut. Coconut palms are grown in more than 93 countries of the world, with a total production of 5.4 billion tons per year (Nwankwojike et al., 2012). Each part of the tree has its own commercial value that can be formed into various products and usages, including catering for traditional and modern needs. In the present market, the use of coconut and its products as a functional food, nutritional food, pharmaceutical and cosmetics has greater market value and this demand is increasing continuously.

Separation of its husk from the nut (de-husking) constitutes the first and most difficult and dangerous operation in its processing. De-husking is the process of removing the outer covering called husk from the coconut to get two important commercial products such as copra or dried kernel and fibre or coir (Nwankwojike et al., 2012). Although coconut is of immense economic importance to both the industrialist and rural area, the processing of coconuts after harvesting involves de-husking, which is presently labour intensive.

Currently, de-husking of coconuts is still widely manually performed. The traditional method of de-husking is by using traditional tools such as hoe, blade or spear. The manual de-husking process requires an operator to use his or her strength and skill to bring the coconut sharply down into the blade, twist the coconut to one side and loosen the husk and detach the fibre from the shell. This action is repeated several times until the entire fibers are removed from the shell. This process is not only difficult and dangerous but also requires necessary skill and strong wrist. Presently, Onoja (2021) has developed a commercial mechanical de-husking device. When a study was done on the machine, it was discovered that some components were lacking and there is need to redesign and fabricate it to lift the mechanization of coconut processing. Coconut has considerable significance in the national economy in view of rural employment and income generation. There is need to support the perishing industry with a vision to make its farming more productive and remunerative.

MATERIALS AND METHODS

The coconut de-husking machine was fabricated using mild steel plates, stainless steel rods and mild steel gears. The coconut fruits worked with were of local varieties which were obtained from Naka market, Gwer-West, Benue State, Nigeria. The major components of the developed coconut de-husking machine are frame, de-husking unit, conveying unit, barrier plates/clearer, handle and bearing housing. The frame the main supporting structure upon which other components of this machine were mounted. The frame is a welded structure constructed from 50 x 50 x 50 mm angle iron with dimensions of 690mm length, 480mm width and 400mm height.

The de-husking unit comprise of two rollers, two roller shafts and two spur gears. Each roller was formed by welding twelve metal spikes (Φ16 x 5mm) on an 80mm diameter mild steel pipe mounted on a roller shaft. Each of the roller shafts is a mild steel rod of 35mm diameter and 920mm long supported at both ends by ball bearings with a gear mounted at right ends. Also, driving handle was mounted on flywheel at the right end of the driving roller shaft while driven roller shaft will drive the conveying unit of the machine. The coconut de-husking machine is very easy to operate and requires one operator.

The designed device includes a plurality of cylindrical drum rotating in opposite directions effectively toward each cylindrical drum include a plurality of penetrating spikes sharpened to penetrate effectively the engage husk portion of the coconut fruit. The interaction of these drums in combination with the gripping action of the spike will serve to tear away the husk from the nut leaving the nut. The coconut de-husking device was driven by the combination of flywheel with handle and spur gears that is linked to the de-husking drums. The flywheel is attached with handle and connected to the gears and rotates at the speed with the driving gear.

Generally, the function of the coconut de-husking device was to scrap the coconut skin and the coconut husk from the skin. It is a portable device which can be operated indoors or outdoors. The flywheel with handle which rotate the gears and double spiked rollers that were connected to them. The speed of the spiked rollers was controlled by the flywheel with handle and adjusted via an operator. During operation, the coconut to be de-husked is fed through into the hopper and fall by gravity to the de-husking chamber containing the set of rotating spiked rollers. An engagement of the driver cause an energy transfer to the shafts which will in turn squeeze the coconut husk, detach the husk from the gear arrangement, and convey the de-husked coconut to the chute chamber where they were collected in a container/basin. The existing coconut de-husking machine was studied and redesigned under the following components.

Shaft

Design of spike

Design of hopper and frame

Design of gears

Design of flywheel

Cover

The component parts were designed considering the shape and size of the coconut.

Design of Shaft

The spiked roller shafts were fabricated with bearings between the shaft and the end caps so that the spiked roller shafts were free to spin independently of the shaft. The shaft of the spiked rollers was placed into the block of the mounts and attached via bolts to the frame assembly. The minimum shaft diameter needed to avoid failure of the shaft was calculated thus;

For solid shaft having little or no axial loading, the equation below can be used (Ugwu and Ozioko, 2015).

d3 = (5)

Where d = diameter of the shaft in mm

kb = combined shock and fatigue factor for bending moment (1.5)

kt = combined shock and fatigue factor for torsional moment (2.0)

Mb = resultant bending moment Nm (2.538 Nmm) (Nwankwojike et al., 2012)

Mt – resultant torsional moment

Ss = 42 MPa for shaft with key way (Khurmi and Gupta 2008). Assuming a factor of safety (FS) of 1.5, the maximum permissible shear stress for shaft with key way is calculated to be:

Ss = = = 28MPa = 28 N/mm2 (6)

Mt = 6.005 N-m (Nwankwojike et al., 2012)

ds3 =

ds3 = 0.293m ≈ 30mm

Design of Spiked De-Husker

The dimensions of cylinders were designed in a manner to obtain effective mesh with coconut husk, based on the assumptions: coconut contacts with cylinder at an average angle of 300 contact sector and 1/6th of width of coconut should be inserted into the intermediate space between cylinders. The adhesion between fibers and the husk is greater than that between the shell and the husk, hence, separation occurs at the husk-shell interface. The thickness of fibre is in the range of 20 – 40 mm. the dimension of spikes was selected to get effective penetration with coconut. The spikes are attached to cylindrical rollers by welding.

Design of Hopper and Frame

The coconut de-husking device was designed to a size of 354mm length, 178.2mm breadth and height of 100mm. the frame height and the hopper assembly top constitutes the total height of the de-husking device. The frame height was designed to be 428mm and the hopper assembly top 307mm, equivalent to 735mm total height of the de-husking machine.

The dimension of the hopper will be calculated by using the volume of a rectangular pyramid by the equation below;

Volume (V) = (udo et al., 2015) (7)

V= = 2102760 mm3

Where L is length of the hopper = 354mm

W is the width of the hopper = 178.2mm

H is the height of the hopper = 100mm

Design of Gear

The existing machine requires two standard spur gears (steel) with 210 pressure angle. The driving gear was designed to have 44 teeth, addendum and pitch circle diameter of 188mm and 160m respectively while number of teeth, addendum and pitch circle diameter of the driven gear were 44 teeth, 248mm and 220mm respectively. The flywheel and the handle were mounted on the driving roller shaft while the driven roller carry the 44 teeth gear.

The recommended driven speed is 29.48 rpm (Nwankwojike et al., 2012). Hence, the driving speed was determined using the following relation:

$$N_1T_1 = N_2T_2 \quad (8)$$

Where N1 = Speed of the driving gear

T1 = Number of teeth on driving gear (44)

N2 = speed of the driven gear (29.48rpm) and

T2 = Number of teeth of driven gear (44)

A flywheel with handle attached to the shaft carrying driver gear, which propel the movement of the follower gear, which in turn allow the follower gear to transmit energy to other systems through a series of connections.

Flywheel Design

A flywheel is the heavy rotating mass which was placed between the power source (handle) and the driven machine to act as a reservoir of energy. It is used to store the energy when the demand of energy is less and deliver it when the demand of energy is high. The method adopted for the design of flywheel for the coconut de-husking machine was analytical method and the various parameters were determined in regard with flywheel design. Geometrical dimensions and material condition were selected such that: flywheel should not exceed the diameter of 250mm. coefficient of fluctuation of speed 0.1, mean speed of flywheel, 120 rpm, mass of flywheel, 10kg, material of flywheel, mild steel with density of 7840kg/m3.

The mass moment of inertia of this disk is given by

$$I = tR4 \quad (9)$$

Where I = Mass moment of inertia of the disk (kg-m)

= Mass density of flywheel material of disk (kgm3)

t = Thickness of disk

R = Outer radius of disk (m)

Design of Cover

A rectangular cover of 346mm x 148mm was fabricated to protect the coconut from going out of the hopper during de-husking process.

The area of the rectangle is given by the relation,

$$A = LB \quad (10)$$

A= 346 x 148

A = 51208mm2

Where A = area of the rectangular cover

L = length of the rectangular cover

B = breadth of the rectangular cover

De-Husker Construction and Assembly

The coconut de-husker modification was done using standard components locally available in the market and properly selected to meet engineering requirements of the machine. Each component was fabricated according to designed dimensions and assembled such that like the frame, hopper, gears and spike drums were welded while other components were fastened using bolts and nuts.

Power Requirement

The power, p required for de-husking of one coconut by this machine was determined from the following relation given by Nwankwojike et al. (2012).

$P = FVa$ (11)

The hand force cannot exceed 45N (international encyclopedia of ergonomics and human factors, 2009).

$Va =$ (12)

Where Dx1 is pitch diameter of the driving gear (160mm = 0.16m given earlier)

$Va = = 0.247m/s$

The power $P = 45 \times 0.247 = 11.11W$

The various components, their design and modification of some of the components are shown in table 1 below.

Machine Drawings

The drawings for this coconut de-husking device adapted from the design calculations are presented in the figures, 1-6.

Evaluation of the Coconut De-Husking Device

The modified coconut de-husking device was evaluated on the basis of its performance. The machine was evaluated under the parameters shown in table 4.

Time Taken to De-Husk

The time taken for de-husking a coconut was taken using a stop watch.

Output Capacity

The de-husking capacity of the machine was determined from the average de-husking time required to de-husk one (1) coconut which was measured in nuts per hour.

De-Husking Efficiency

The de-husking efficiencies and broken coconut percentages was calculated using the formula as given by Nwankwojike et al. (2012).

De-husking Efficiency = (13)

Broken Percentage = (14)

At first, the husk was weighed on the weighing balance after de-husking on the de-husker. Then the remaining husk present in coconut was removed completely from the de-husked coconut manually to know the total weight of husk.

RESULTS AND DISCUSSION

The result of the performance evaluation of the coconut de-husking machine are presented in table 3. The table 3 shows the details of the performance evaluation carried out using 20 coconuts grouped into 4 each for five trials. The result of the performance evaluation of the modified coconut de-husking machine is presented in table 3 above, which shows that the de-husker device had a high de-husking average efficiency of 85%. The value is above the efficiency of the existing machine designed by Onoja (2021) and close to the values obtained by Roopashree (2017) – 86%, Adzimah and Turkson (2015) – 87.90% and Nwankwojike et al. (2012) – 93.45%. The interpretation of the efficiency obtained in this research is that the de-husking device was able to de-husk most of the coconuts successfully without breakage.

Table 4 also shows that the diameter had an average throughput capacity of 65 nuts per hour which is greater than the capacity of 60 nuts per hour obtained by Onoja (2021) but the value is less than 70 nuts per hour by Nwankwojike et al. (2012). The value obtained is 65% less than the values obtained by automated de-huskers of Thomas et al. (2017) at 200 nuts per hour, Roopashree (2017) at 195 nuts per hour and Ramadurai et al. (2019) at 200 nuts per hour. The value obtained in this study shows that the human power is not sufficient in de-husking large amount of coconuts. The broken coconut percentage from table 4 was 15%. This indicated that most coconuts were de-husked whole. The manual coconut de-husking device was successfully redesigned and fabricated. The performance evaluation of the device was carried out which gave a de-husking efficiency of 85%, throughput capacity of 65 nuts per hour and broken coconut percentage of 15%. The following recommendations were made: The manual coconut de-husking machine can be modified with the use of electric motor. Further research should be carried out in order to increase its efficiency.

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TABLES

Table 1: Summary of Component Modification

S/No.	Component	Material	Modification
1	Shaft	Mild steel	Φ30 X 700mm
2	Hopper	Mild steel	(354 x 178.2 x 100)mm
3	Spikes	Mild steel	32 Nos Φ6 x 20mm
4	Cover	Mild steel	346mm x 158mm
5	Flywheel	Mild steel	Φ250 x 15mm
6	Bolt and Nut	Mild steel	M7 x 15mm

Table 2: Performance Evaluation of the Coconut Modified De-Husking Machine

S/No.	No of Coconut to be de-husked	Average weight of whole coconut (kg)	Time taken to de-husk coconut (s)	Average weight of de-husked coconut (kg)	No of fully de-husked coconut	No of partially de-husked coconut	Average weight of husk	Efficiency (%)	Capacity (fruits/hr)
1.	4	1.40	218	0.90	4	0	0.50	100	66
2.	4	1.20	229	0.80	3	1	0.40	75	63
3.	4	1.30	215	0.90	4	0	0.40	100	67
4.	4	1.10	225	0.60	3	1	0.50	75	64
5.	4	1.20	222	0.70	3	1	0.50	75	65
Total	20	6.2	1030	3.9	17	3	2.3	425	325
Mean	4	1.24	206	0.78	3.4	0.6	0.46	85	65

Table 3: De-Husker Broken Coconut Percentage

Whole Coconut Count	Broken Coconut Count	Broken Percentage (%)
20	3	15

FIGURES

Figure 1: Frame and other Components of the Coconut De-Husker

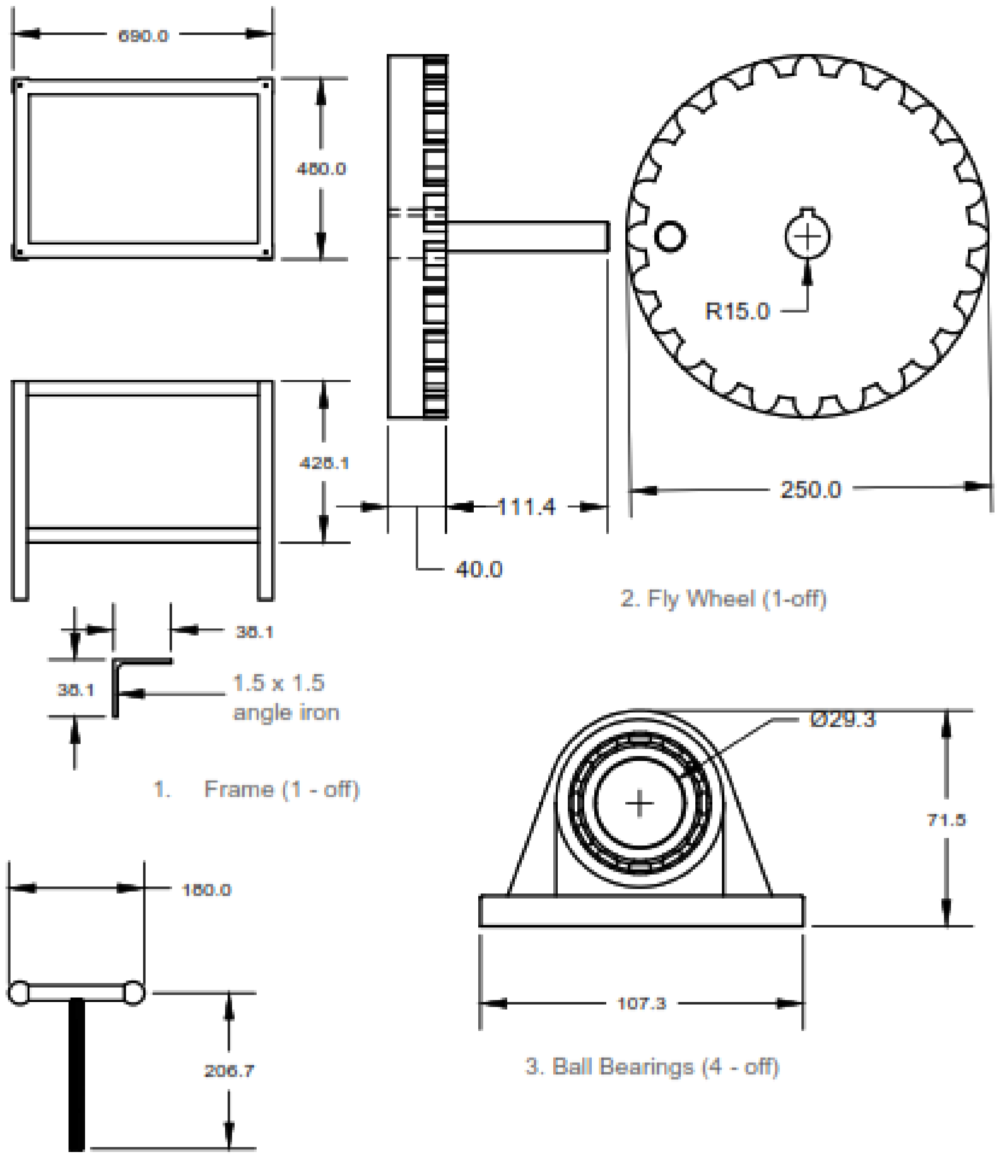


Figure 2: Hopper and Cover Detailing of the Coconut De-Husker Modification

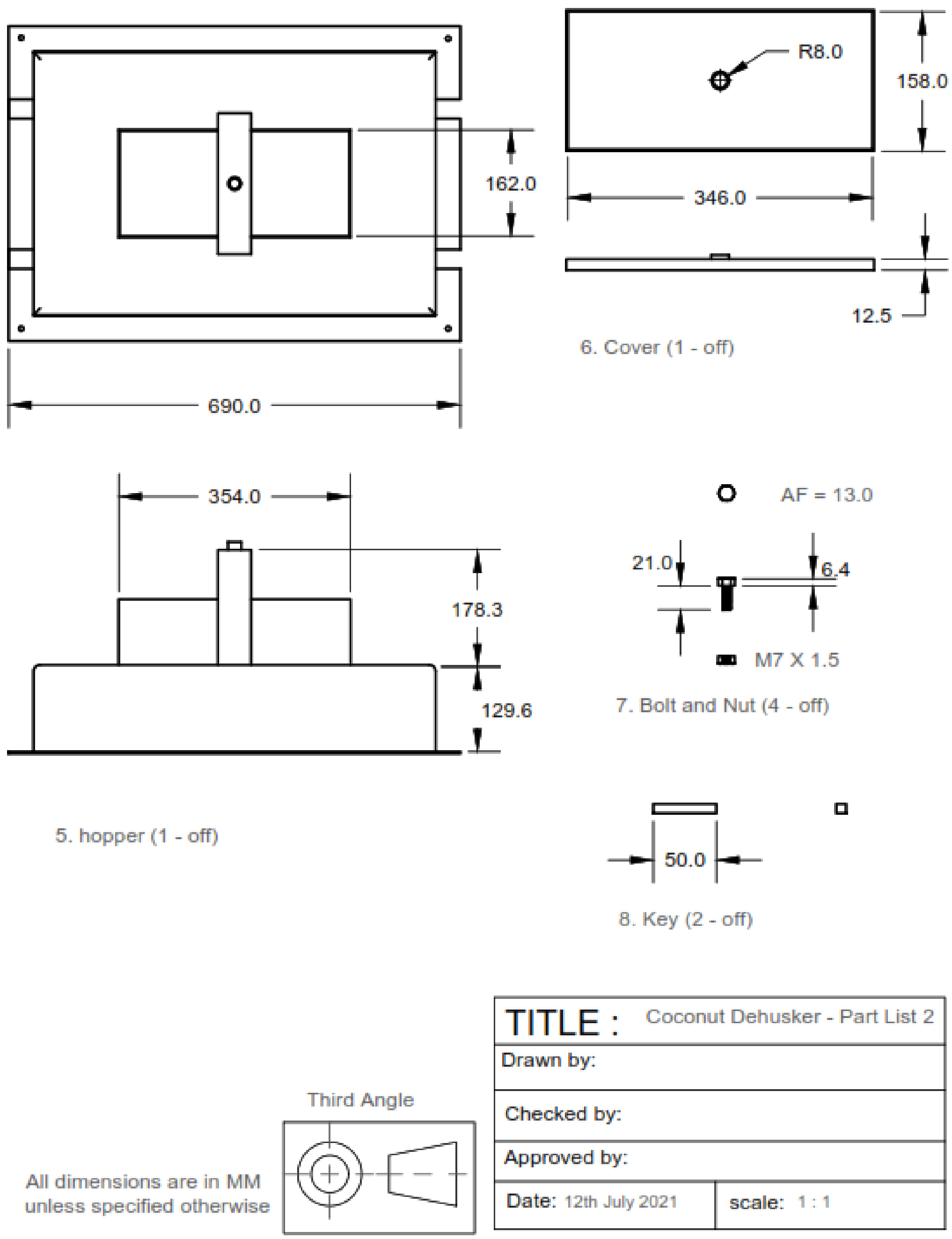
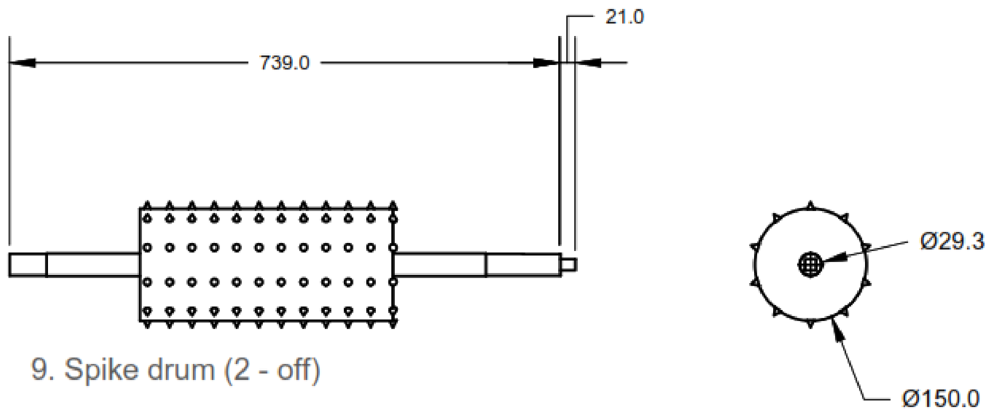
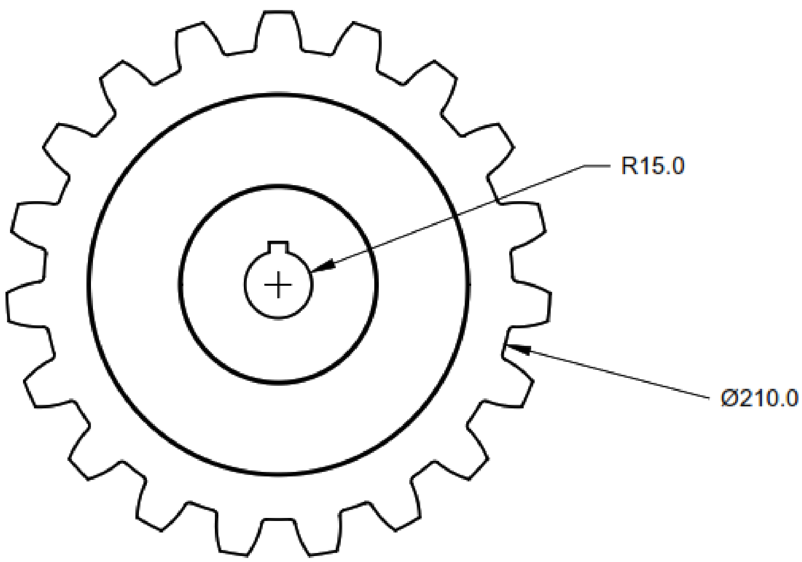


Figure 3: Gear Design of the De-Husker



9. Spike drum (2 - off)



10. Spur Gear (2 - off)

Figure 4: Third Angle Orthographic Projection of the De-Husker

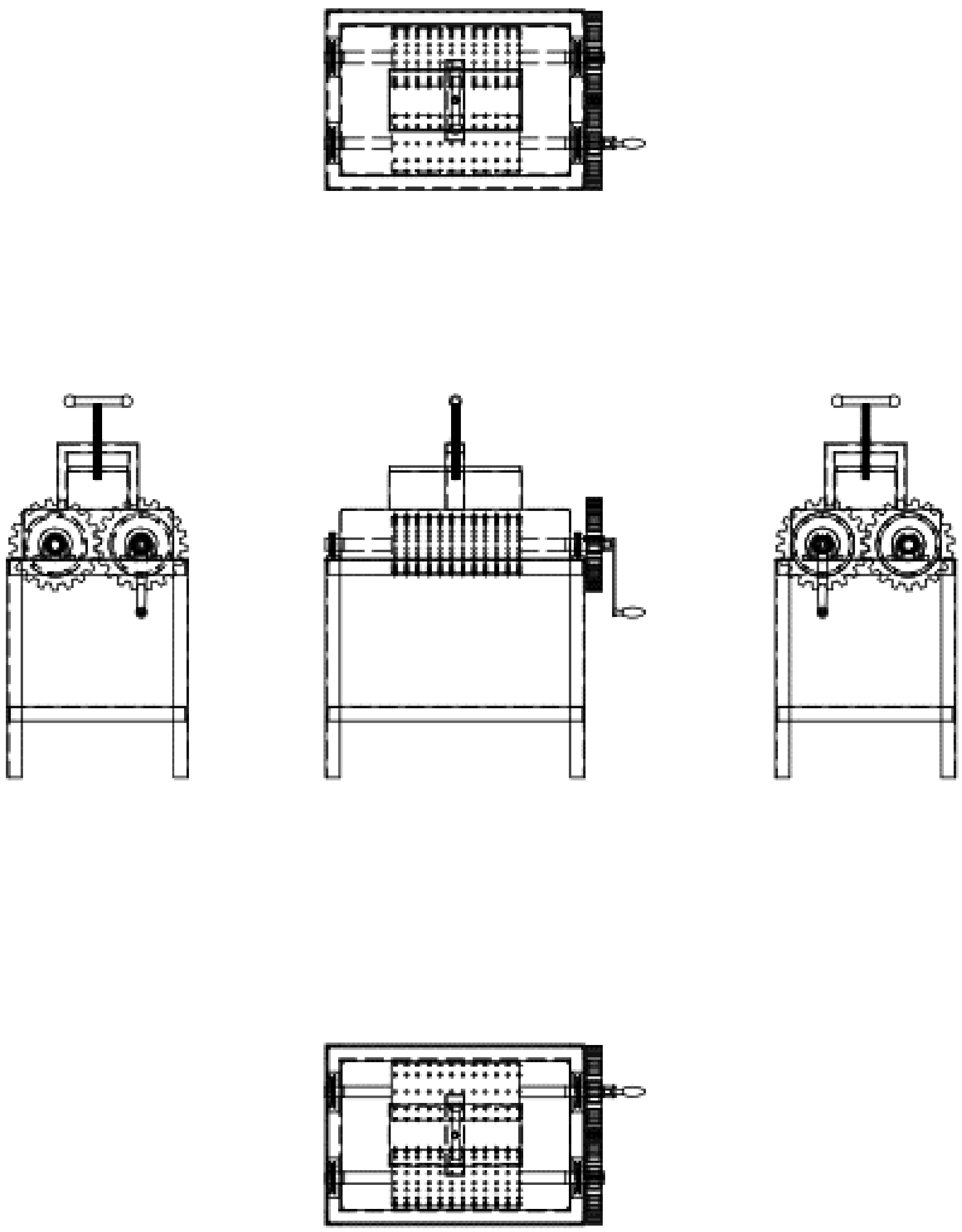


Figure 5: The Assembled Drawing of the De-Husker Modification