Design and Fabrication of a Pedal Powered Paddy Rice Thresher

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ABSTRACT
The main objective of this study was to design and fabricate a hand operated pedal powered thresher for threshing, separating, and cleaning rice paddies. The major components of the machine include threshing, separation and cleaning units. Threshing operation is achieved by rotational motion of a cylinder fitted with beater spikes above a stationary grid which results in the removal of the paddies from the bulk straws. After being beaten out, the grains fall into the cleaning unit which consists of a sieve that undergoes a reciprocating motion. The machine is simple, less bulky and the ergonomic considerations in the design allows for comfortable use and can easily be operated by either male or female. The designed and fabricated pedal powered paddy thresher fitted with winnowing equipment substantially reduces human drudgery in threshing at an affordable cost and also reduces the time used for threshing operation on small farms. Threshing was efficient for moisture content between 20% and 23%. Total power required by the machine was 84 watts operating at 400 rpm. This power is produced through human operated pedal mechanism. Performance test revealed that the efficiency of the machine was 92% with a through put of 90 kg per hour.

Keywords: Threshing, separation, cleaning, efficiency, cylinder, pedal mechanism, solidworks software

1. INTRODUCTION
Rice *(Oriza spp)* is after wheat, the most widely cultivated cereal in the world and it is the most important food crop for almost half of the world's population [1]. National rice consumption in Kenya is estimated at about 300,000 tonnes against an annual domestic production of between 45,000 to 80,000 tonnes. This huge gap between consumption and production is met through importation of rice. In 2008, rice imports into Kenya were valued at Ksh 7 billion [2]. To reduce this dependency on importation, include decreased consumption which is not a viable option, increasing tariffs on imported rice, increasing the area under current cultivation, increasing productivity and proper post-harvest practices to minimize loss and improve quality. Majority of farmers in Kenya grow rice in small scale, they therefore lack enough capacity to acquire appropriate equipment such as combine harvesters to be used for threshing. They therefore resort to manual means of threshing rice like: smashing ears of rice with hard objects to separate the paddies from the ears or straws, sometimes pedal operated threshing drums are employed in fairly big farms, or even driving trucks or tractors on the un-threshed rice. Manual threshing is tedious, time consuming and above all results in too much post-harvest losses which can be in the range of 1-15%. According to Earth trend, [3], postharvest food loss translates not only to human hunger and financial losses to farmers but also results in tremendous environmental wastes. In Kenya, rice production has remained low both in quantity and quality because of the inefficient production and processing techniques. This research was conducted to determine ways of reducing post-harvest losses and tediousness resulting from traditional methods of rice threshing. The study involved designing of a pedal powered thresher from scrap metals and affordable power transmission element and to make the whole system affordable to the small scale farmers.

2. MATERIALS AND METHODS

2.1 Machine Design
The whole work of designing and fabrication was done under following phases: design considerations, designing of prototype of paddy thresher using *Solidworks* software, fabrication of designed the model and testing of the machine. The machine comprises of the following main components and sub components: (1) threshing unit: - threshing drum, Shaft, threshing teeth, hopper, casing, (2) power transmission system: - bicycle/ primary drive, chain, sprocket, Flywheel/secondary drive, (3) Sieving unit (4) Collecting unit and (5) Frame.

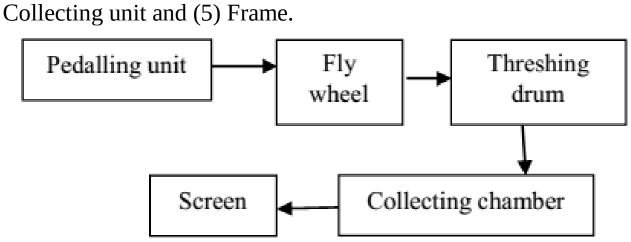

Figure 1: Block Diagram of the threshing system

2.2 Working Principle of Machine Design
The threshing component works on the principle of impact force, while the screen uses the principle of reciprocating motion to cause the agitation of the paddy grain. The machine is operated by applying force through pedalling a bicycle which through the first chain converts higher speed to the middle shaft, the middle shaft

consists of one larger sprocket of higher number of teeth and a smaller sprocket with lesser number of teeth which is connected to the rider sprocket. The larger sprocket transmits rotary motion to another smaller sprocket mounted on a second shaft thus causing the shaft to rotate an increased speed. This second shaft has a sprocket of same size mounted on it and is connected to the shaft at the threshing unit. The other sprocket connects to the larger sprocket on the first shaft. The shaft also has a fulcrum system that provides reciprocating motion to the screen. The threshing operation is achieved by rotational motion of a cylinder fitted with beater spikes above a stationary grid which results in the removal of the paddies from the bulk straws. After being beaten out, the grains fall through a concave grid into the cleaning unit which consists of a sieve that undergoes reciprocating motion. The grain, then get collected in the collecting tray which will hence direct them to the final collecting container for transportation.

2.3 Design Considerations of Machine Components

Before designing the CAD model, it was essential to consider various components necessary for the designing such as; threshing drum size and speed, power required for threshing and frame design. Among the threshing methods, the threshing of grain through impact force at an average speed (350 to 500 rpm) provide minimum seed damage. Therefore, threshing of rice paddies is based on the principle of impact force generated by beating action of the spikes. The main design considerations for the entire machine include; dried rice paddy suitable for threshing by this machine should have moisture content of 20% to 23% to ease the removal of the paddy grain from the stalk, overall height of the machine to facilitate ease of operation by a rural farmer of average height, overall width and breadth of the machine for purposes of storage space in the rural farmers granaries, weight of the equipment for easy portability during operation on and off farm, the material to be used to be cheap and easily available to peasant farmers and the material should be strong for machine durability and should not rust resistant or if otherwise be painted.The machine has the five main components that have to be designed and be fabricated accurately for its efficient working. These are: the threshing unit, power transmission system, screening unit and a collecting unit.

2.3.1 The threshing unit

It is the most integral part where separation of the paddies from the straws take place. For maximum efficiency of the machine, this part require proper and accurate design of the components. It is comprised of the following components:

2.3.1.1 Threshing drum

It is the part that holds the threshing teeth and as well as the powering shaft in position. For efficient functioning of this component, the following design considerations were made; be made from lighter material to reduce the weight, its diameter be able to suck entire straw holding paddy grains, an average height of rice stock is 1.2 m and a diameter of 300 mm with a drum length of 400 mm were chosen.

2.3.1.2 Threshing teeth

This is the part that beat the paddies off the stalk, it consists of six angle line steel bars of length 400mm mounted along the circumference of the threshing drum. The material used for this component is designed to be lighter and stronger for durability.

2.3.1.3 Shaft

This is the component that provides power to all the moving components in the threshing unit. The following design consideration must be adhered to: the shaft should be strong enough to carry the weight of the threshing drum, threshing teeth and the sprocket and the overall weight of this machine should also be favourable to facilitate the powering of the machine through man power.

2.3.1.4 Hopper

This is the part where the paddy stalk is being fed into the threshing drum. The design/orientation of this component should ensure that there are no paddy grains escaping from it during threshing time.

2.3.1.5 Casing

It is the part that cover the entire threshing unit. It has two very critical functions as far as ergonomics and machine performance is concern. These include the following: it minimizes post- harvest losses of the paddies by ensuring there are no grain scattering during threshing time and also protects the operators from the danger of jumping stones, stalk, or any part of the machine that may be blown away by the rotating component of the threshing unit. The unit consists of two casings; upper casing and lower casing. The latter made permanent but the first is able to open and close in case for any operation required inside the threshing unit. Both parts are made from mild steel plate of 0.5mm thick to withstand the impact force of the blown away items.

2.4 Power Transmission Unit

The power transmission system comprises of the following components:

2.4.1 Bicycle/primary drive

This is the powering source of the entire machine. The machine is powered by the operator through pedaling the bicycle. The machine is designed to use a bicycle pedaling mechanism. The larger sprocket of the bicycle is connected to a smaller one at the flywheel unit. The bicycle is estimated to generate power output of about 75 watts. This is actually the power a human being can generate for 8 hours while circling [4]. This again poses a very important fact to consider in the design of the machine as it means for the machine to operate, the total power required in all the components should be equal to or no less than 75 watts.

2.4.2 Power Transmitting Chains

The power transmission mechanism (Fig. 2) used is the bush roller chain. These chains are used for transmission of power, when the distance between the centres of shafts is short. These chains have provision for efficient lubrication. A bush roller chain is extremely strong and simple in construction. It gives good service under severe conditions. There is a little noise with this chain. This chain may be used where there is a little lubrication.

To ensure zero failure of the machine caused by this component; centre and length of chain distances were determined

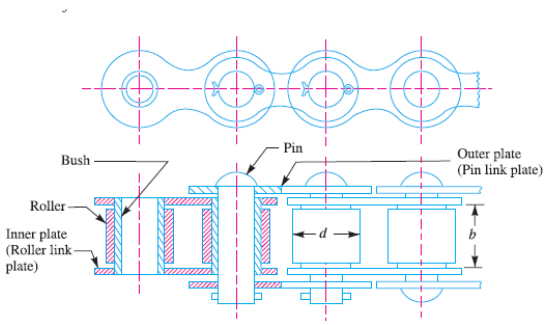

Figure 2: Power Transmitting Chains

2.4.3 Sprockets

These wheels have projecting teeth of special profile and fitted into the corresponding recesses in the links of the chain as shown in fig. 3. This is the component that determines the amount of speed to be achieved at the shafts connected to different moving machine components.

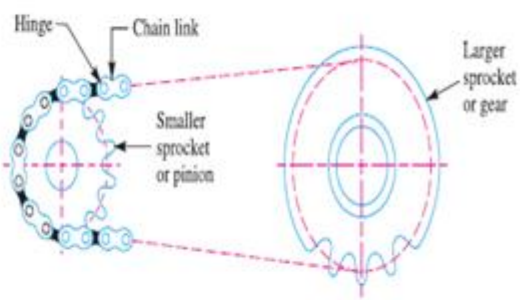

Figure 3: Sprockets

2.4.4 Flywheel/secondary drive

This is a mechanical device specifically designed to efficiently store rotational energy. It smoothens the power output of an energy source. It consists of 4 sprockets and two shafts. The first shafts carry one smaller sprocket and a larger sprocket, the smaller sprocket is connected to the larger sprocket on the bicycle and the larger sprocket transfer motion to the smaller sprocket on the second shaft. The second sprocket on shaft is connected to the sprocket at the drum hence transfer motion to the drum. The second shaft also provides reciprocating motion on the screen which helps in paddy grains agitation. The following design parameters were determined; the size of the shaft to carry the sprocket, the size and type of the bearing, the rotational speed (rpm) of each shaft and the twist angle on the shafts

2.4.5 The frame

The frame supports the entire machine and also holds the components of the machine in the exact position they are designed. The frame is designed from a stronger material that is able to hold the weight of all the parts and withstand the vibration and shock that the machine experiences during the operation. In the frame designed, the following parameters were determined: the total weight the frame shall carry shall be calculated and the total bending moment the frame shall experience shall calculated

2.4.6 Screen

This system separates small paddies from large chaffs that find their way through the threshing unit into the screen. The component was designed to have: a light unit to impose less load on the operator, the reciprocating motion to be faster to enable fast sieving of the paddies, less noisy to reduce fatigue on the operator and the screen size designed to allow the paddy grains to pass whilst retaining the chaffs.

2.4.7 Collecting unit

The collecting unit collects the screened paddies and channels them to the farmer's collecting system. The component was designed to have the following; large unit to collect all the paddies falling from the screen, mounted at a considerable distance from the screen to ensure air through natural convection passes through the falling grains to blow lighter material and made to slope to ensure grains roll naturally by gravity to the containers.

2.5 Other design consideration

On the basis of literature, various parameters which can affect the threshing of rice paddies were selected and analyzed3.0 as follows:

2.5.1 Size of rice grains

Grain size a very important parameter in the determination of the size of the screen to be used in the design. Rice grain size is the geometric mean of the three dimensions i.e. length, breath and thickness. The size was calculated using the following expression (Kachru *et al.*, 1994)

$$Size = (LxBxT)^{1/3} \tag{1}$$

Where L=length, B=Breadth, T=Thickness Different sizes of rice paddies were obtained from Dominion farm and measured by "Vernier calliper". Long grain measured 8mm, medium grain ranged from 5 to 6mm and short grain ranged from 4 to 5 mm. On the basis of paddies dimension the screen size were set.

2.5.2 Size of teeth

Size of teeth is defined as a size which directly comes in contact with the rice paddies during the process of threshing. The surface area of the teeth would determine whether the machine would cut the stock or agitate the grains by impact force. The length of the teeth would also determine the volume of the paddies to be threshed in a given time. Overall length of the teeth was 400 mm.

2.5.3 Slope provided to the sieves

Slope of sieves facilitates the passing of paddies though the sieve and trash are moved on the lowest part of the sieve. It works on the principle of discharge by gravity. Through observed it was determined that a slope of 3° was enough for this purpose.

2.5.4 Feed Rate.

Feed rate also affects the efficiency of machine times of threshing time. It can be controlled by selecting the proper method of feeding or by designing the hopper having a proper size. Through observation it was determined that a bunch of paddy straws would be held against the rotating drum and once threshed the waste to be thrown aside.

2.5.5 Clearance between teeth and casing

It is defined as the distance between the drum casing and surface of teeth. Clearance has a great effect on threshing efficiency of a threshing machine. Lesser clearance leads to more breakage of pea grains and also work load imposed on the power source and more clearance leads to more grains not threshed. Because the whole paddy stock is not through in the drum, this parameter was found not to have much effect on the machine efficiency

3 FABRICATION OF DESIGNED MODEL

Designing of machine was done by using “SolidWorks” software and fabrication was done by using different materials. Initial trails were taken in order to calculate effectiveness of machine. The main components of threshing equipment include; frame, threshing unit, sieve/screen, collecting trays, transmission system, feeding hopper and bearings. Various components and their drawing are described below:

3.1 Frame

Frame A frame of mild steel of 600 mm x 510 mm x1000 mm (Length x width x height) was fabricated with tube iron of size 30 mm x 30 mm x 10 mm.

3.2 Shaft

A shaft of mild steel was machined into different lengths of 300mm, 600mm and dia. 16 mm. Its ends were fitted with the bearings fitted on frame.

3.3 Threshing drum

A threshing drum of diameter 300mm and length 350 mm was fabricated using mild steed flat plate of 300mm by 2mm (width by thickness)

3.4 Threshing teeth

These plate were constructed from angle line mild steel of dimension 20mm by 20mm by 2mm (length x width x thickness)

3.5 Sieve/screen

The sieve was made from mild steel plate of thickness 0.5mm and galvanized iron having holes of 8 mm by 8 mm. The sieve was tapered by 3^0 from the horizontal with wide open side towards the discharge end of trash.

3.5 Upper cover and lower cover

The upper cover and the lower cover of machine were fabricated by mild steel plate of 0.5 mm thickness. Main function of upper cover and lower cover is to cover the upper part of the rotating part of the threshing unit.

3.6 Hopper

Hopper was fabricated by using mild steel plate. Main function of the hopper is to control the feed rate without choking of machine. A hopper plate is provided with to control the passage of material from the hopper.

3.7 Collecting trays

Tray was constructed from mild steel plate of 0.5mm thick and proper slope was provided for collection of clean grains at the outlet.

3.8 Bearing

These were provided at the ends of the shaft for smooth and frictionless running of shaft. The bearings also help to maintain the clearance between blades and sieve.

4 RESULTS AND DISCUSSION

4.1 Chain drive

Since the distances between the shafts is short, steel power transmitting chains which have provision for efficient lubrication are used in this design for two major reasons: to transmit motion and power from one shaft to another and to avoid slipping usually encountered in rope and belt drives. The chains are made up of rigid links which are hinged together in order to provide the necessary flexibility for warping around the driving and driven wheels. The wheels have projecting teeth and fit into the corresponding recesses, in the links of the chain. The wheels and the chain are thus constrained to move together without slipping and ensure perfect velocity ratio. These toothed wheels are known as sprockets.

4.1.1 Velocity Ratio of Chain Drives

The velocity ratio of a chain drive is given by

$$V.R = \frac{N_1}{N_2} = \frac{T_2}{T_1} \quad (2)$$

Where N_1 = Speed of rotation of the smaller sprocket in r.p.m.,

N_2 = Speed of rotation of the larger sprocket in r.p.m.,

T_1 = Number of teeth on the smaller sprocket,

T_2 = Number of teeth on the larger sprocket.

4.1.2 Centre Distance

Let T_1 = Number of teeth on smaller sprocket,

T_2 = Number of teeth on larger sprocket,

p = Pitch of the chain, and also,

x = Centre distance

$$X = \frac{p}{4}\left[K - \frac{T_1+T_2}{2} + \sqrt{\left(K - \frac{T_1+T_2}{2}\right)^2 - 8\left(\frac{T_2-T_1}{2\pi}\right)^2}\right. \quad (3)$$

4.1.3 Length of Chain

The length of the chain (L) must be equal to the product of the number of chain links (K) and the pitch of the chain (p). Hence mathematically,

$$L = K.p \quad (4)$$

The number of chain links may be obtained from the following expression, *i.e.*

$$K = \frac{T_1+T_2}{2} + \frac{2X}{p} + \left(\frac{T_2-T_1}{2\pi}\right)^2 \frac{p}{x} \quad (5)$$

In order to accommodate initial sag in the chain, the value of the centre distance obtained from the above equation should be decreased by 2 to 5 mm.

4.1.4 Pedaling unit

The pedalling unit forms the powering section of the thresher and consist of a larger sprocket that connects to a smaller sprocket by a chain. The average circle a human being can make in one minute has been experimented to be 60 rpm. This is the speed at which the operator operates on. From literature, the pedaled power that can be generated by human being is estimated to be about 75 horsepower. This will thus be the power source expected to be exerted on the pedalling sprocket. The pedaling sprocket require high number of teeth so as to ensure high revolution speed at the flywheel section. Therefore, 48 teeth has been chosen because it is the largest sprocket available in the market.

Therefore, the angular speed from the sprocket will be calculated as follow;

$$\omega = \frac{2\pi N}{60}$$

The torque on the sprocket will be given as

$$T = \frac{p}{\omega}$$

4.1.5 *The flywheel unit*

The flywheel unit consist of a 2 larger sprocket of same size and a smaller sprocket both mounted on same shaft so as to move as same speed of 180 rpm and in same direction. In the design of this unit, the following factors are determined in order to avoid failure of the overall machine; speed and size of sprockets, diameter and length of the shaft.

4.1.6 *Sprocket size and speed*

The velocity ration will be obtained from the following formulae;

$$V.R = \frac{v_1}{v_2}$$

Where V.R= velocity ratio

V_1= velocity ratio of larger sprocket

V_2 = velocity ratio of the smaller sprocket

The number of teeth on the smaller sprocket shall be selected according to the table 1 shown below,

Table 1: Sprocket sizes and their respective speed

Type of chain	*Number of teeth at velocity ratio*					
	1	2	3	4	5	6
Roller	31	27	25	23	21	17
Silent	40	35	16	27	23	19

The number of teeth are taken as 16 from the table above. The smaller sprocket (sprocket No. 1) of 16 teeth is chained to the pedaling sprocket and is rotated at a speed of 180 revolutions per minute. This sprocket has the purpose of increasing the speed from 60 rpm to the required 180 rpm. The larger sprocket (sprocket No.2) is of same teeth as the pedaling sprocket that is 48 teeth. The sprocket transfers speed to the thresher drum and rotates at a speed of 180 rpm. The other sprocket (Sprocket No.3) sprocket transfers force to another sprocket system that will be converting rotational motion to linear reciprocating motion to agitate the screening unit. The sprocket will also be rotating at a speed of 180 rpm.

4.2 Determination of the Threshing Drum Volume

The threshing drum volume is needed in order to determine the capacity of the threshing drum and the weight as well. The thresher drum is designed to have a diameter of 300mm and length of 500mm. The construction is made from mild steel plate with a thickness of 1mm. The objective of the design of this unit is to make the unit as light as possible but with enough strength for prolong life of the machine. The drum is to have 6 threshing teeth made of angle line steel measuring 25 mm by 25 mm and with a thickness of 2mm.

The circumference of drum = πD

$=\pi \times 300$

=943mm

Volume of curve section $TV_c = L * W * TV_c$ (6)

Where

L=drum length (7)

W=circumference

T=drum thickness

V_c= 500× 943 × 1= 471500mm^3

Volume of sides $V_s = \frac{\pi D2_t}{4}$

Where

D = diameter

T = plate thickness

$V_s = \frac{\pi \times 300^2 \times 1 \times 2}{4}$ = 141372mm^3 (8)

Volume of the teeth V_t = $(25^2-23^2)\times 500\times 6$=288000mm^3

Total volume = $v_c+v_s+V_t$ = 471500+141372+288000 = 900872mm^3 = 9.009×10^{-4}

4.3 Evaluation of Weight of Threshing Drum

The weight of the threshing drum was determined in order to know the amount of load being exerted on the shaft by the threshing drum. Therefore the weight of the threshing drum is expressed as:

$$W = Mg$$

$$M = \rho V$$

Where W = the weight of threshing drum (N)

M = mass of threshing drum (kg)

g= acceleration due to gravity (9.81m/s^2)

ρ= the density of the drum (7850 kg/m^3)

V = the volume of the cylinder (m^3)

M=7850 ×9.009× 10^{-4}=7.072kg

W=7.072 × 9.81=69.4N

4.3.1 *Weight sieving/screening unit*

The screening unit is made as light as possible from a good material that has a good strength to reduce wear and tear during working life of the material. Therefore mild steel plate with 1mm thickness was chosen for this unit. The rice sieving unit consists of steal tray with perforated bottom (screen) of size 28 mm. The screen sieves through reciprocating motion to cause agitation in order to separate chaffs from paddy grains. The dimensioning of the screen is at 340mm by 500mm while the height of the steel tray being 100 mm. The tray was mounted by hanging it in a slanting position by a flexible material in order for the chaffs to slide off by the force of gravity. The agitation provided by a rotating sprocket that connects to the tray by crank shaft mechanism.

Volume of the unit $= (340 \times 500 \times 10) - (338 \times 498 \times 9)$ $=185084=1.851\times 10^{-4}mm^3$

Mass of unit$=7850\times 1.851 \times 10^{-4} = 1.6kg$

Weight of the unit$=1.6\times 9.81 = 15.696N$

Figure 4 show the isometric view thresher drum unit fitted with teeth and a shaft.

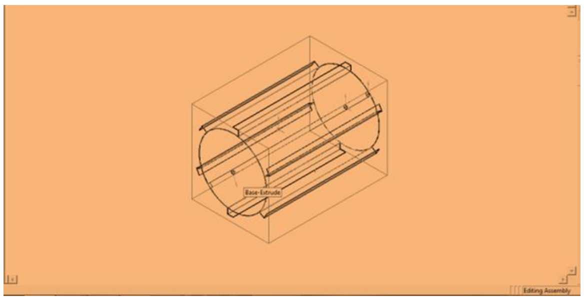

Figure 4: The rice sieving unit

4.4 Power required for threshing rice paddies from the straw

The power required to thresh rice paddies from the straws is expressed as:

$$P = T\omega \qquad (9)$$

$$\omega = \frac{(2\pi N)}{60}$$

$T = Fr$

T = torque of the drum (Nm)
ω = angular velocity (rad/s)
N = speed of the threshing drum in rpm/min=400rpm
F = the impact force required to thresh millet
r = the distance of point of force application from axis of rotation (m), (Ndirika, 1997; Abu, 2006).

$$\omega = \frac{(2\pi N)}{60} = \frac{2\pi \times 400}{60} = 42rad/sec$$

$F = mg = (4.8 \times 10^{-5} \times 7850) \times 9.81 = 3.7N$

$T = 3.7 \times 0.325 = 1.203$ Nm

$$P = 1.203 \times 42 = 51watts$$

4.4.1 Power required for reciprocating the screen

$P = T\omega$

$$\omega = \frac{(2\pi N)}{60}$$

$T = Fr$

T = torque of the drum (Nm)
ω = angular velocity (rad/s)
N = speed of the sprocket drum in rpm/min
F = weight of the screen (N)
r = radius of the sprocket (m)

$T = Fr = 15.696\times 0.05 = 0.7848NM$

$P = 0.7848 \times 42 = 32.87$ watts

4.5 Shaft Analysis

For shaft subjected to combined twisting and bending moments (Fig.5). Based on maximum sheer stress theory:

$$d^3 = \frac{16}{\pi S_s} \sqrt{\{(K_b\ M_b)^2 \times (K_t M_t)^2\}} \qquad (10)$$

S_s = the allowable stress= $40 \times 10^6\ Nm^{-2}$

K_b = the combine shock and fatigue factor applied to bending moment

M_b= the bending moment (Nm)

K_t= the combine shock and fatigue factor applied to torsional moment

M_t=the torsional moment

(Hall *et al.*, 1980)

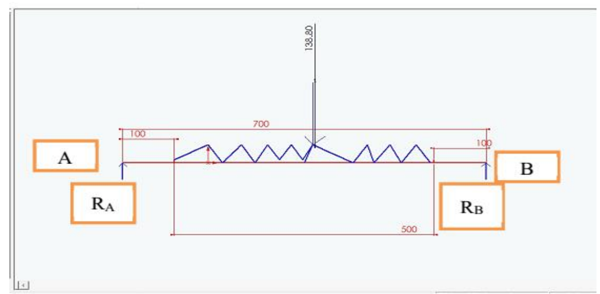

Figure 5: Bending moment diagram

Taking moments at B
From

$$R_A = \frac{wb}{2l}(2a + b)$$
$$= \frac{138.8 \times 0.5}{2 \times 0.7}(2 \times 0.1 + 0.5)$$

$R_A = 34.7$
$R_B = R_A = 34.7$

$$M_{MAX} = R_A(a + \frac{R_A}{2w})$$
$$= 34.7(0.1 + \frac{34.7}{2 \times 138.8})$$
$$= 7.8075Nm$$

T = FR
F = mg = $7.074\times 9.81 = 69.4$

T = 69.4×0.325 = 22.53Nm

$$d^3 = \frac{16}{\pi \times 40 \times 10^6} \sqrt{\{(2 \times 7.8075)^2 \times (2 \times 22.53)^2\}}$$

$d = 0.0182m$=18.2mm

Hence a diameter of 20mm is appropriate

4.6 Determination of angle of twist

The angle of twist helps to know whether the diameter of the shaft is safe to carry the applied load. According to Hall et al. (1980), the amount of twist permissible depends on the type of load

application and varies about 0.3 degree per meter for a machine tool shaft and about 3 degrees per meter for line shafting.
Therefore, angle of twist (θ) for solid shaft is given as follow:

$$\theta = \frac{584 M_t L}{C d^4} \tag{11}$$

Where,
L= the length of shaft (m)
M_t= the torsional moment (Nm)
C= torsional modulus (Nm^{2})
d = diameter of the shaft (m)

$$\theta = \frac{584 \times 22.53 \times 0.7}{79 \times 10^9 \times 0.02^4}$$
$$= 0.7286°/m$$

5 PERFORMANCE TEST

The fabricated paddy rice threshing machine was subjected to performance test and was found to thresh rice effectively. Grain losses and mechanical damages were found to be minimal and hence negligible. The machine threshes 90 kg of rice per hour.

6 CONCLUSION

The thresher substantially reduces the human labour involved in threshing at an affordable cost and also reduces the time used for threshing operation on small farms. The machine further reduces the post- harvest losses experienced in small scale rice growing field which is a bigger challenge in most of the developing countries. For ease the removal of the paddy grain from the stalk, threshing was efficient for rice with moisture content between 20% and 23%. Total power required by the machine was 84 watts operating at 400 rpm. This power is produced through human operated pedal mechanism. Performance test revealed that the efficiency of the machine was 92% with a through put of 90 kg per hour.

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8 REFERENCES

[1]. Rice Policy-World Rice Statistics (WRS). International Rice Research Institute, IRRI web. http://www.irri.org/science/ricestat, **2009**

[2]. National rice development strategic plan Government of Kenya, Ministry of Agriculture, **2016.**

[3]. Earth trends 28(2):37-40, (2018) web. http://www.earthtrendswri.org/pdf_library/feature/agr_fea_ dissapear pdf

[4]. https://en.wikipedia.org/wiki/Human_power

[5] K. N. Agrawal, E. V. Effect of thresher drive linkage design on human physiological. Agric Eng Int: CIGR Journal, **2013.** 1-9.

[6] Olumuyiwa B. Ajayi1 Buliaminu Kareem, O. R. Comparative Quality And Performance Analysis Of Manual. Ondo State: Innovative Systems Design and Engineering**. 2014.**

[7] Satapathy, G. C., and S. K. Mohanty. Ergonomical Evaluation of Pedal Operated Paddy Thresher. Progress Report of All India Coordinated Research Project on Ergonomics and Safety in Agriculture (Bhubneswar Centre). Orissa University of Agriculture and Technology, Bhubneswar. **2005**

[8] Ouézou Yaovi Azouma M. Design of throw-in type rice thresher for small scale farmers. Indian Journal of Science and Technology **2009** Vol.2, 1-5.

[9] Hall AS, Hollwen KOA, Laughum H, 1980. Schaum's Outline of Theory and Problem of machine design. Metric Selection. McGraw-Hill Books Company. New York. Council

