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Research Article

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Modification of Threshing Component of IAR Millet Thrasher

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Abstract The modification of millet thresher was carried out Evaluation of the threshing component was also done with white variety of millet at two levels of feed rates. It was observed to have a threshing efficiency of 97% at 2 kg/hr feed rate. The machine is capable of removing premature grains which from lighter reduce grain breakage and separation of stalk from the grain with total power requirement of 0.7064W (0.947hp). A maximum throughput capacity of 102.89Kg/hr was recorded. Also the mechanical grains damage corresponding to 7.5% was obtained.

Keywords Thresher, Modification, Threshing component

Introduction

Pearl millet is cereal crop in the grass family, gramineae. It is the most drought tolerant of all the cereal and is best adapted to the dry tropics of Africa and Asia where it constitutes one of the major stapled food crops. In Africa, Nigeria is the leading producer of pearl millet. ‘Dauro’ millet is one of the three types of pearl millet (*pennisetum typhoides)* and Hubbard produced in Nigeria. The other two types are Gero millet and Maiwa millet. ‘Dauro’, ‘Gero’ and ‘Maiwa’ are local (*Hausa*) names for the pearl millet types in the Northern part of Nigeria. Both ‘Dauro’ and ‘Maiwa’ are photosensitive, late maturing and are produced in limited areas of the savanna region but ‘Maiwa’ is produce more extensively. The production of ‘Dauro’ and ‘Gero’ is presently localized to the south of latitude 11^o N and on height altitude areas (600-950 m above sea level) of the northern part of Nigerian. The whole area of its production lies largely in the southern Guinea savanna and extends in the immediate part of the northern guinea savanna. In contrast, ‘Gero’ is non-photosensitive and early maturing and is produced more extensively throughout the savanna region of the country than both Dauro and Maiwa [1]. These crops are mainly grown in harsh environments (rain fed and temperature more than 20^{o}C). Where the yields of other crops are very poor are less prone to disease and pests [2]. ‘Dauro’ and ‘Gero’ is produced more extensively in North West than in North East State. This is probably connected with the historic length of time ‘Dauro’ has been associated with Kaduna state. According to oral history, the Hausas were trading the millet during the trader by barter [1]. ‘Gero’ or Dauro is usually grown after groundnuts either during the same cropping season or in the following season. Consequently, the field fertilization of ‘Dauro’ is achieved generally by this cropping sequence. Late planting of ‘Gero’ or ‘Dauro’ also gives the advantage of the field carrying two crops with separate growth cycles per cropping season. This also saves the labour which could have been used in clearing a new piece of land for the cultivation of Gero.

Material and Method

The Improvement Considerations

In the improvement of the millet threshing machine, the following factors were put into consideration are:-

(i) Angle of repose the slope angle of 60^0 to be horizontal for easy grain flow
(ii) The peripheral speed of cylinder will be in range of 91 – 136 m/s.
(iii) Cylinder concave clearance the free end of the beaters and concave will be in the range 30 mm – 35 mm.
(iv) The power requirement all transmission was made to take place at one end of the shaft.
(v) The threshing capacity
(vi) Availability of construction material Cost of material, to be affordable to both small and medium scale farmers.
(vii) Simplicity in construction.
(viii) Safety was considered by locating the operators stand away from all rotating part and crop particles propelled by the machine.

Establishments of the Parameters

The cylinder speed

The cylinder speed was chosen to be 124.8 m/s. This was in accordance with [2].

The shaker Speed

The optimum speed of shaker was selected as 160 rpm. The reciprocating motion of the sieve helps separate the chaff from the seed [4].

The concave clearance

The concave clearance between the threshing drum and concave was fixed at 10 mm; this was in accordance with [5]. The concave was made of mild steel and metal square bar of gauge 12 thickness.

The sieve hole sizes/shape

This depends on the shape and size of the grain. The shape of millet is oval; therefore, the shape of sieve hole was made rectangular. The chosen diameter of the hole was taken to as 15 - 20% more than the equivalent diameter of millet seed or grain [4]. The value of D_e calculate was fund to D_e = 1.2 mm, therefore, the sieve hole size was chosen to be 4 mm.

The equivalent diameter D_e, was expressed mathematically as [6]

$$D_e = \left(\frac{6Vp}{\pi}\right)^{1/3} \quad (1)$$

Where;

D_e = equivalent diameter (mm)

V_p= particle or grain volume (mm)

Design Calculations

Pulley size determination

The drive speed is the criteria for which the pulley sizes. Design groove pulley was used on the threshing shaft and this pulley was driven by prime mover [9]

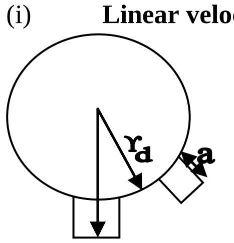
$$N_1 D_1 = N_2 D_2 \quad (2)$$

Where;

N_1 & N_2 = speed of driving and driven pulley respectively (rpm).

D_1 & D_2 = diameter of driving and driven pulley (rpm)

(i) **Linear velocity of drum**



$\gamma e = rd + a$

Where;

a = length of beaters

γe = effective of radius

V = ꞶƆγ

Where,

V = velocity

ꞶƆ = angular velocity

γ = radius of drum

Determination of belt size

The selection of Belt size depends on the length, thickness and properties of the materials from which the belts were made. The thickness and the properties are based upon the power to be transmitted.

The belt length was based on [6] standard given as:

$$L = 2C + 1.57\frac{(D-d)^3}{4C} \quad (3)$$

Where;

L = effective belt length (mm)

C = center distance from driven to driving pulley (mm)

d = diameter of driven pulley

D = outside diameter of driving pulley

Determination of angle of contact

The estimation of angle of contact was achieved using the relationship [7].

$$\Theta = 180 - \frac{(D - d \times 60)}{4} \quad (4)$$

Where;

Θ = angle of contact

Estimating angle of contact for the pulley on the thresher Θ_1

Determination of power required to detach grains from the torque was given by [9].

$\tau = Fr$

Where;

τ = torque (kNm).

r = radium of threshing drum (0.23m)

F = total force on shaft (N)

Total force on shaft = weight of beater on the cylinder drum plus weight of threshing cylinder.

Mass = volume x density of the beater materials.

Where;

$$\pi = \frac{22}{7}$$

D = diameter of beater (m)

L = length of beater (m)

ρ = density of rod (7. 83 x10^3 kg /m^3)

g = acceleration due gravity (9.81m/$s^{2)}$

N = number of beater (66)

Weight of threshing cylinder

Weight = volume x density of material

Volume = area between the outer and the inner circumference x cylinder length

$$\text{Area} = \pi\frac{(D^2 - d^2)}{4} \quad (5)$$

Where;
D = outer side diameter (mm)
d = inner diameter (mm)
Area = πd (thickness)
Length = mm
Volume = area x length = mm^3
Volume = m^3
Weight = kg
Total force on shaft = N
torque τ = Nm

$$\tau = (T_1 - T_2)\frac{D_2}{2} \quad (6)$$

Where;
T_1 & T_2 = tension is tight and slack side respectively
D_2 = diameter of three pulley (m)

$T_1 - T_2 = (T_1 - T_2)\ ^{1.0}/_2$

$$T_1 - T_2 \quad (7)$$

$^{T}{}_{1}/ T_2 = e^{\mu o cosec\ \beta}$ [10]

Power, $P = \frac{2\pi N_2}{60}$

Determination of minor shaft diameter for the thresher

Determination of correct size of shaft diameter and length is such that it can transmit power under the stated operating and loading conditions. It also involves material selections so that the stated conditions are economically and efficiently met.

ASME code equation for solid shaft having or no little axial loading is

$$d^3 = {}^{16}/_{\pi}\delta_s \sqrt{[(KtMt)^2 + (KbMb)^2]} \quad (8)$$

Where;
d = diameter of shaft (mm)
d_s = design stress ($55x10^6$ N/m^2) [6]
K_b & K_t = combined shock and fatigue factor applied to bending and tensional moment respectively
(K_b = 1.0 & K_t = 1.5)
M_t = tensional moment (N_m)

Major components

The prime mover powered major component of millet thresher consists of the hopper, the threshing, shaker unit, stalk outlet and frame.

The Hopper

The hopper was constructed from 1.5 mm mild steel which is rectangular in shape, with all sides slanting inwards. It forms the feeding chutes through which millet heads are fed in to the cylinder casing and it is inclined at angle 60^o to the horizontal plane.

The Threshing Unit

This is the part where the threshing of the crop is carried of 250 mm and 1360 mm length cylinder beater and a concave made of 3 mm mild steel formed into semi-circle with circular opening. The cylinder made from steel shaft. The beater are made of flat bars of 5 mm the thickness, 640 mm length and spaced a 100 mm apart. The clearance between the end of the beaters and the concave is maintained at 100 mm.

The Sieve and Shaker

The shaker carries the sieve for the cleaning of the grain. It separates the grains from some unwanted materials by its reciprocating motion, while the seeds pass through the sieve holes and are collected from the grain pan located below the sieve. The shaker was slightly in inclined for the ease of separation of seed and chaff. The sieve is rectangular in shape of length and width 1610 mm and 430mm respectively. It is made of 1.5 mm sheet metal.

The frame

The frame makes up the mounting support for all other units and is made of 1465 mm x 1095 mm angle bar. The overall dimension is 1465 mm x 1095 mm x 1375 mm.

Working principles

The thresher works on the rotating impact principle. The cylinder designed to rotate at 192 m/s during operation. The ear head of millet feed uniformly into the hopper, the ear head falls by gravity into the rotating cylinder and whirled round between the perforated concave and the rotating cylinder. This impact thus brings about threshing the chaff and grains fall through the concave openings by gravity into the stationary sieve while the straw exit through the straw exit. The threshed millet is then directed to a collecting pan by a salted metal sheet beneath the sieve.

Experimental procedure

The experiment was carried out on white variety of millet. The thresher was evaluated at two levels of feed rate (2 kg/hr and 4 kg/hr), five levels of cylinder speed (91.65, 95.5, 105.3, 124.8, 136.5 m/s respectively) and a constant concave clearance of 10 mm and moisture content of samples was determined using the procedure detailed by [3]. The samples treatments of feed rate (f) and cylinder speed (N) were obtained. There were two replications for each cylinder speed at different feed rate and the average was taken. The harvested material was weighed using weight balance and lysimeter before being fed into the thresher. After threshing, the materials collected from the chaff and grain outlets were weighed and recorded. The performance was evaluated based on the following. The threshing efficiency, mechanical grain damage and throughput capacity were calculated as shown in table 1

Performance Evaluation

The experiment was carried out with two levels of feed rate one crop variety and five cylinder speeds. Total combination for each experiment was twenty (20). The formulae for evaluating the various performance parameter of the thresher were obtained from [12].

The parameter calculated were: - Threshing efficiency, visible grain damage, percentage and output capacity (%). All the parameters were determined as given by [12].

Threshing Efficiency, T_e (%)

This can be defined as the ratio of quantity of threshing grains in sample to the total quantity of grains in sample, to determine the threshing efficiency.

$$T_e = 100 - [\frac{Qa}{QT} \times 100] \quad (9)$$

Where,

T_e = Threshing Efficiency (%).

Q_u = Quantity of unthreshed sample (kg)

Q_T = Total quantity of grain sample (kg)

Damaged grain, M_d (%)

This is defined as grain damaged as the ratio of the quantity of broken grain collected in sample to the total quantity of grains in the sample.

$$M_d = \frac{Qb}{QT} \times 100 \quad (10)$$

Where,

M_d = Damage grain (%).

Q_b = Quantity of broken grains in the sample (kg)

Q_T = Total quantity of grain sample (kg)

Throughput capacity, TC (kg/hr)

This is the total material quantity that passes through thresher in a given time. The grain output capacity.

$$T_c = \frac{QT}{t} \quad (11)$$

Where,

T_c = output capacity, (kg/hr)

Q_T = Weight of the grain collected per unit time, (kg)

t = threshing time, hours.

Results and Discussion

The performance of the thresher was evaluated to show the effect of the various cylinder speeds and their effects on threshing efficiency, mechanical grain damage and through put capacity at different feed rate are shown in Table 1.

Effect of Threshing Efficiency (T_e)

From Table 1, it can seen that threshing efficiency increases with increase in the cylinder speed from 92.50% to 97% (at 2 kg/hr feed rate) and 90.88% to 96.63% (at 4 kg /hr feed rate). This was because at higher threshing speed, the impact force is greater, causing more grains to thresh. But as the cylinder speed increased, threshing efficiency dipped due to high impact which the chaff and grain damage, maximum (97%) 91.65 m/s (2 kg/hr) and (96.6%) 105.3 m/s (4 kg/hr) respectively.

Table 1: Summary of Various Performance Parameters at two levels of feed rate

Peripheral	T_e (%)		M_d (%)		T_c (kg/hr)	
Speed (m/s)	2 kg/hr	4 kg/hr	2 kg/hr	4 kg/hr	2 kg/hr	4 kg/hr
91.65	92.50	90.88	1.25	3.13	6.53	23.47
95.5	95.00	88.50	1.20	1.38	3.92	26.92
105.3	94.00	96.63	-	-	24.09	47.87
124.8	97.00	93.00	-	7.50	22.55	35.51
136.5	94.25	93.37	3.00	5.37	46.45	102.89
Mean	94.55	92.48	1.82	4.35	20.71	47.33
SD	1.46	2.71	0.83	1.45		

SD = standard deviation

Mechanical grain damage M_d.

From Table1 mechanical grain damage increase from 1.25% to 3% at 2 kg / hr feed rate and from 3.13% to 5.37% at 4 kg/hr feed rate as the cylinder speed increase at a particular moisture content, the impact force increase, thereby causing more grain damage with the maximum damage at 91.65 m/s (2 kg/hr feed rate) while maximum grain damage at 136.5 m/s (4 kg/hr feed rate) From table 1, the throughputs capacity increase with an increase in cylinder speed and feed rate with the minimum 3.92 kg /hr (at 2 kg feed rate) and maximum 102.89 kg/hr (at 2kg/hr feed rate) at 91.65 m/s and 136.5 m/s respectively. This was because at high cylinder speed the threshing time decreases giving the machine room to handle more grain.

Conclusion

The existing IAR millet thresher was modified and performance evaluation of the threshing component carried out. The best combination for the thresher as seen from Table 1 and also was achieved with cylinder speed of 91.65 m/s and 2 kg/hr feed rate, 35 mm concave clearance and moisture content18.75% d.b. The threshing and grain damage at 91.65 m/s and feed rate of 2 kg/hr 97%, and 0% with the 91.65 m/s at feed rate 4 kg/hr are 93%, 7.5% and 3.87% respectively. Also, the throughput capacity corresponding to this was 22.55 kg/hr and 35.51kg /hr.

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Appendix