International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2023.9.6.4

Volume 9, Issue 6
June - 2023

Design and Development of Agricultural Waste Shredding Machine

Lasisi I.O[1], Adeyemi A.J[2], Yusuf S.As[3], and Abdulkadir M[4]

Department of Mechanical Engineering

Waziri Umaru Federal Polytechnics Birnin Kebbi, Kebbi State

Nigeria

ABSTRACT

After the harvest of most agricultural products, the waste generated is in large quantity. In most cases, this waste is either completely abandoned, destroyed or burnt. There is a need to look for alternative ways through which these wastes can be converted and useful for other purposes. This work developed a shredding machine using locally available materials. The machinecan shred these agricultural wastes into smaller pieces that can be used for animal feed. The machine consists of the following parts the machine frame, the feeding unit, and the transmission section; the materials used in constructing these parts include sheet metals, angle irons, shafts, bolts, and pulleys. The machine performance was evaluated using rice straw. The evaluated parameters include the efficiency of the machine and throughput capacity. The operational speed during the testing includes 350rpm, 650rpm and 970rpm,respectively. Maximum shredding efficiency of 90% was achieved when the shredding speed was 970 rpm. The maximum value of throughput capacity of 2.77kg/min was obtained at a shredding speed of 970rmp, while 1.92kg/min was obtained at a shredding speed of 350rmp. The machine demonstrated good performance and was cost-effective and relatively cheap for small and medium farmers.

Keywords: Agricultural waste, Development, Waste shredding machine.

1. INTRODUCTION

Agriculture's waste is residues from crops, fruits, vegetables, sawdust and livestock. These wastes are produced during various agricultural operations. They form non-product outputs of products and processes, which may necessarily contain some essential nutrients that benefit mankind. Generating these wastes is a function of the system and types of agriculture processes that demand their usage. This can be in the form of liquid, slurries or solids. (Obi *et all*, 2016). Agriculture is one of the major occupations of most rural settlers in Nigeria. The wastes produced in large volumes can be converted and reused as animal feeds. Farmers are compelled to either burn these wastes or find alternate means of disposing them because they lack the basic knowledge on how to reuse them or consider the nutritional benefits of all these large volumes of waste.(Adewumi et al, 2002). For countries, particularly those in sub-Saharan Africa, those need to make continuous investments in agriculture, management of the waste from such investments demands planning. It was observed that about a million tons of agricultural waste are generated globally (Agamathus, 2009). However, with the introduction of an agricultural multi-purpose shredding machine, these wastes are managed and converted to useful forms such as manure, animal feeds and soil preservatives. In the case of soil preservation, the machine is used to shred the wastes into smaller sizes,which can easily be decomposed and used as a nutrient for the animals. This,in turn, is an alternative to commonly used agrochemical substances that adversely affect plants and soil.

1.2 RELEVANCE OF THIS RESEARCH WORK

The wheat straw and rice straw produced as agricultural waste can be used effectively as animal feeds. Since these wastes are generated in abundance, they can be converted into animal feeds by using a shredding machine. The feeds can be preserved and used as feeds, adding to their daily nutritional benefits. Most animals find it difficult to feed on the waste directly from the farm; this results from the large size and sharp edges of the discarded waste. This research work will provide a solution by producing a machine that breakdown large size of these agricultural waste for easy consumption by animals and also aid easy digestion.

2.LITERATURE REVIEW

Agricultural practice in Nigeria employs about 70-80 % of the labour force (Abdulkadir *et al.*, 2020). Most especially during the time of planting and harvesting the crops. It supplies the population with basic food needs and provides the import sector with the

C. author's Email: lightnday17@gmail.com

necessary raw materials. During this period, large sums of wasteare generated,whichhas become a concern to all the major stakeholders in agricultural practice, including the government(Abdulkadir *et al.*, 2020). Therefore, there is a need for urgent concern and intervention on how these wastes can be converted to useful purposes for both humans and animals. One such intervention is the process of shredding the waste. Shredding is a process or method of cutting items or materials into smaller pieces or tearing something into shreds.

Abdulkadir *et al.(*2020) developed ashredding machine for beans stalk and evaluated its performance by investigating the shredding efficiency and throughput capacity. He uses Responsesurface methodology (RSM) to maximise the machine's efficiencyat operational Speeds of 360rpm, 650rpm, and 975rpm with sieve apertures of 20mm, 30mm, and 40mm, respectively. He obtainedMaximum shredding efficiency of 93% when the shred aperture was 20mm at a shredding speed of 975rpm. He reported the maximum throughput capacity to be 6.10kg/m at a speed of 975rpm and a minimum value of 5.14kg/m at 325rpm, respectively.

Mahadev et al (2020) They developed a Shredder machine that focusing on chopping of agricultural wastes such as coconut leaves, areca leaves etc., and this chopped waste can then be used to prepare the vermin-compost. Concepts were developed with reference of 4 completely different device machines and in operation processes. This idea is incorporated by considering the security issue users in operation atmosphere and maintenance. Focusing the need of users requirement and purchasing for capability, a prototype was fabricated. The main parts in this equipment which are three-phase motor, bearings, structural frame, cutter and a shaft. The shredder equipment frame is built by using a material mild steel and stainless steel for cutter tip preparation. There are two cutters are mounted on the shaft. The power derived from the electrical motor which is transmitted to cutter shaft through a belt drive assembly. Cutting action is formed within the chopping house because of the result of tensile, friction, and impact result in chopping method. The chopped waste is finally collected at the bottom.

Joseph (2002) presented a paper shredding machine with an automatic feeding mechanism. This machine could shred 20 sheets in a single feed of 22.86 cm width.

Ming (2006) also presented a paper shredding machine with multiple blades attached to two rotary cutters. The blades were distributed in a non-equiangular manner. A major limitation of the machine was the reduction in efficiency as the amount of shredded residue increased.

Fauzia et al (2017) They presented a paper that deals with a detailed study & design procedure of a paper shredder machine. A detailed study of various parts of shredder machine like stand (frame), transmission system and cutting system are made and designed separately. The first part deals with the study of cutting system of a shredder machine i.e. types of blades, different profiles, its dimensions, its alignment, advantages and disadvantages of different types of blades. The second part includes problem definition, objectives, procedure of design with the detailed design of each component of the cutting and transmission system i.e. designing a blade and making certain modifications in it and the frame. The third and last part deals with the design of 3D model of various parts on Dassult Systems "SOLIDWORKS 2014" and its motion study and the analysis of the stand in ANSYS 15.

The main objective of this work is to develop a small-scale agricultural waste shredding machine with locally available materials. The machine will reduce the time used for chopping or thrashing the crop residues by hand. The machine is also affordable for local farmers.

3. DESIGN CONSIDERATIONS AND CCALCULATIONS

The shredding machine is made up of various components, which include:

i. Body casing
ii. Shredding unit
iii. Straw discharge unit
iv. Hopper (feeding chute)
v. Electric motor and some other essential parts like the bearing, shaft, frame etc.

In the desiginig of the machine severals factors were considered. These factors include

i. Economic Factors
ii. Mechanical Factors
iii. Operational Factors, and fabrication, and operation of the machine.

3.1 **Design calculations**

Power Require by the machie

The power required for machine was considered using the expression according to (Shigley, 1986).

$P = F \times V$ (1)

Giving that:

P = power (Nms^{-1})

DOI: 10.31695/IJASRE.2023.9.6.4

F = Force of shredding N
V = Velocity (ms−1)
The force required for shredding is given as;
$F = m\omega^2 r$
F = force required to shred waste material
m = mass of shredding blades,
ω = angular velocity of shaft.
$\omega = \frac{2\pi N}{60}$
N speed of shredding (rev/m).
The power delivered by the shaft is given by
$P = F\omega r$ (2)

3.2 **Calculation of bolt for the frame** Shear stress factor was for considered for bolt during the construction of frame for the machine. And this expression was use according to (Shigley and Mischke, 2005).

$$Se = \frac{F_{Max}}{\frac{\pi d^2}{4}} \quad (3)$$

Givin that:
Se = allowable endurance stress of mild steel = 107.969 × 103KN/m
Fmax = Fmin + weight of rice straw filling the hopper
Fmin = force due to total weight of the machine without load = 0.8KN

$$d = \sqrt{\frac{4F_{max}}{\pi S_e}} \quad (4)$$

d = 0.0035m = 3.5mm . 4mm bolts were selected for fastening the machine to the frames.

3.3 Determination of v– belt length

The length of the belt was determined for the operation of the machine was based on (Khurmi and Gupta, 2006) and Abdulkadit et all 2020, expression for the V-belt length is given as;

$$L = \frac{\pi}{2}(D_s + D_m) + 2C + \frac{(D_s + D_m)^2}{4c} \quad (5)$$

L = Belt Length
C = Center length between two pulleys
D_s = Pitch diameter of the first pulley
D_m = Pitch diameter of the first pulley
The length of the v-belt pulley was determined to be 50cm

3.4 Calculation of volume of shredder hopper

The volume of the shredder hopper , V_{sh} , were the waste materials to be shredded are fed is obtained from equation (vi). The volume of the shortened rectangular based pyramid is given as

$$V_{sh} = \frac{1}{3}(BH - bh) \quad (6)$$

Giving that:
B = the area of the rectangular base for the big pyramid,
H = the height of the big pyramid,
b = the area of the rectangular base for the small truncated pyramid, and
h = the height of the small truncated pyramid.
Parallelogram prism is given as;

$$V = Bh \quad (7)$$

Giving that:
B is the area of the base shape

3.5 Determination of diameter and speed of Shaft

To estimate the diameter of the shafts used in the machine, the Maximum Shear Stress Theory was applied. This theory according to Khurmi and Gupta, (2005) is appropriate for shafts subjected to combined bending and twisting moments, as it is the case with the shafts in this machine. It is also suitable for mild steel shafts, (which are ductile materials). The shafts used in the machine are made of mild tough steel. The diameter of the shaft was determined using the maximum stress theory (Hall et al., 1980)

$$d = \left[\frac{16}{\pi s}\left(\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)\right]^{\frac{1}{3}} \quad (8)$$

giving that:

DOI: 10.31695/IJASRE.2023.9.6.4

M_b = maximum bending moment on shaft (1000Nmm
M_t = maximum torsional moment on shaft (16540 Nmm)
s = allowable shear stress for steel (310 N/mm^2)
K_t ,K_b = fatigue and shock factor for torsion and bending moments (1.5 and 1.0).
The diameter of the main sharft is 65mm.This shaft rotates within the shredder chamber and it is equipped with knife-edged. These knife edge sharp edges welded on the shaft allow shredding of the waste materials to be possible as it rotates in the chamber. The shaft speed of the shredder, V_{ss} , is obtained from equation (2) as in (Khurmi and Gupta, 2005)

$$V_{ss} = \omega_{ss} \times r_{ss} = \frac{2\pi N_{ss}}{60} r_{ss} \quad (9)$$

Giving that:
ω_{ss} =This the angular velocity of the shredder shaft pulley.
r_{ss} = This is the radius of the shredder shaft pulley.
N_{ss} = This is the speed in revolutions per minute of the shredder shaft pulley.

3.6 Power requirement for the prime mover

Power = Force ×Velocity
Power = Force × Screw Circumference × rpm

$$W = P \times \frac{\pi DN}{60} \quad (10)$$

3.7 Determining the shear stress on frame

The triangular bars thickness for the construction of the width of the frame was determined by

$$S_r = \frac{S_e}{F_s} - \frac{S_e}{S_{YP}} \times S_m \quad (11)$$

S_r = This is the Superimposed alternative stress

$$S_r = \frac{(\text{Maximum Stress} - \text{Minimum Stress})}{2}$$

Minimum stress = The weight of the machine components on the frame
Maximum stress = This is all the weights above the plus weight of waste material filling the hopper and force exerted by the electric motor on the machine members.

Table 3.1: Showing cost of production

S/No	MATERIALS	QUANTITY	COST (#)	AMOUNT (#)
1.	2hp Electric motor	1	23,000	23,000
2.	37.5mm flat bar	3000mm length by 2mm thickness	5,000	5,000
3.	Metal sheet	900mm x 1200 x 3.5mm	15,000	15,000
4.	Gauge 12 Electrode	1 packet	2,000	2,000
5.	Body filler	4 litres	1000	4,000
6.	Steel rod 30mm	6000mm	4000	4000
TOTAL				#53,000

Figure 1: Picture of shredding machine

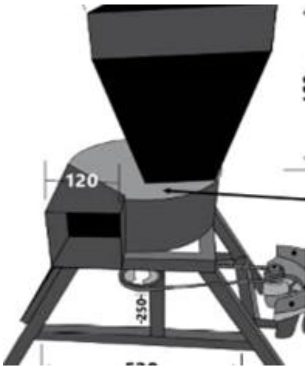

Figure 2. Isometric drawing of the shredding machine

DOI: 10.31695/IJASRE.2023.9.6.4

4.CONSTRUCTION OF THE MACHINE

The construction works were carried out in the school workshop located at the faculty of engineering, the manufacturing procedures adopted for the fabrication of the machine includes marking out operation, cutting, turning, welding, cleaning and painting. The various fabrication process used in the construction of the rice straw shredding machine part explained below.

4.1.1 Fabrication of hopper

The hopper is made up of four welded mild steel metal, which has the shape of cone frustum. The mild steel metal sheet was marked out with the aid of set square, steel rule and scriber. The height of hopper is 460mm, diameter of lower base is 150 mm and the diameter of the upper base is 300 mm.

4.1.2 Shredding chamber

It is a compartment where the rice straws are cutting into smaller piece for animal feed. It is made up of sheet metal of diameter 70 mm and 140mm long with the cutting blade.

4.1.3 Frame

It is the structural unit that carries the load and component of the machine. It is made up of the 2 angle iron having four (4) legs stand 279.4mm each with a rectangular base of 187.4mm by 127.14 mm. A rectangular base 670mm by 420mm was constructed at the top of the frame to support shredding chamber.

4.1.4 Electric motor

Electric motor is used to transmit power or rotational motion of cutting blade through its protruding shaft with the aid of a key that fastened them together.

4.1.5 Assembling of parts

After the components have been fabricated, the following steps were taken to assemble the machine. The electric motor with a protruding shaft at one end was installed on the base made with 35.5mm flat bar and supported with 25mm square hollow pipe held together with a clamp. The next step was to fix the shredding chamber on the base. Using manually operated arc welding machine, the hopper was welded to the shredding chamber diner that permit smooth rice straw into the shredding chamber.

4.1.6 Selection of bearings for the machine

The bearing selection for the machine was based on the available bearings with general standard in the market. They are selected based on the required inner and outer diameter.

4.2 Evaluating the performance of the machine

The developed waste shredding machine was tested and evaluated on two key performance tes4ting, namely the shredding efficiency and the throughput capacity. The experiment was carried out using five kilogram (5 kg) of a rice straw for each three varied motor speed of 350 rpm, 670 rpm and 970rpm using 2 Hp three-phase electric motor as the prime mover. Records of Weight unshredded rice straw (WUSRS), weight of Shredded rice straw (WSRS), their Efficiencies ∑(%), and the time taken were recorded in table 1, table 2 and table 3 respectively.

4.2.1 Shredding efficiency

The shredding efficiency was determined by recording the weight of Unshredded rice straw (WUSRS) before operating machine and also the weight of the Shredded rice straw (WSRS) was taken at the end of operation. All measurement were madein Kilogramme (Kg). The shredding efficiency of the machine at three different speeds ofshredding was determined as follows;

$$SE = \frac{(WSRS)}{(WUSRS)} \text{ X } 100$$

Given that,

SE = Shredding efficiency (%)
WSRS = Weight of shredded rice straw
WUSRS = Weight of unshreded rice straw

4.2.2 Throughput capacity

The throughput capacity for the three speeds was calculated using this equation

$$SE = \frac{(WUSRS)}{(T)}$$

DOI: 10.31695/IJASRE.2023.9.6.4

5. RESULT AND DISCUSSION

The machine was tested and the results of efficiencies for each kilograme of rice straw (2kg, 3.5kg and 5kg) as against variable speed of (350rpm, 750 rpm and 970 rpm) was obtained and recorded in table 4.2, table 4.3 and table 4.4. From each of the tables recorded, it could observed that the efficiencies of the machine increases with an incresases in the speed (350rpm, 750 rpm and 970 rpm) of the machine. This is in agreement with the work of Abdukadir et al, 2020). Table 4.5 shows the result of throuhgput capacity, the result shows that the higher the speed in operating the machine the higher the throughput capacity. At 970 rpm, the machine was capable to shred 2.27kg of rice straw as against 1.92kg, 2.27kg of variable speed of 350rpm and 750 rpm respectively. This result agreed with both the work of (Ayo et al, 2014 and Abdukadir et al, 2020)

Table 4.2: Showing result of rice straw shredding for 350 rmp

No	(USRS) kg	(SRS) kg	∑(%),	Time (min)
1	2	1.7	85	1.7
2	3.5	2.9	82	2
3	5	4	80	2.6

Table 4.3: showimg result of rice straw shredding for 670 rmp

No	(USRS) kg	(SRS) kg	∑(%),	Time (min)
1	2	1.75	86	1.5
2	3.5	3	85	1.8
3	5	4.4	82	2.2

Table 4.4: Showing the result of rice straw shredding for 970 rmp

No	(USRS) kg	(SRS) kg	∑(%),	Time (min)
1	2	1.8	90	1
2	3.5	3.1	88	1.6
3	5	4.4	86	1.8

Table 4.5 showing the throughput capacity of shredding

S no	Operational speed (rmp)	Rice straw (kg)	Time (s)	Throughput capacity (kg/min)
1	350	5	2.6	1.92
2	670	5	2.2	2.27
3	970	5	1.8	2.77

6 CONCLUSION

Agricultural waste shredding machine was designed and constructed using locaally available materials. Performance everluation was carried out. The machine was tested and was found to have performmed objectively with a better efficiency during the the test. The results obtained shows an increase in efficiency when there is an increases in the speed of the machine. Maximum shredding efficience 90% was achieved when the shredding speed was 970rmp. There is an increase in the throughput capacity of the machine when the shredding speed was increased. The maximum value of throughput capacity 2.77kg/min was obtained at a shredding speed of 970rmp while 1.92kg/min was obtained at a sredding speed of 350rmp.

REFERENCE

[1] Obi, f. Ugwuishiwu, B. and Nwakaire, J. 2016 "Agricultural waste concept generation, utilization and management

Overcash, M. R.. Livestock waste management, F. J. Humenik& J. R. Miner, eds. CRC Press, Boca Raton. 1973

[2] Adewumi, M.O. & Omoresho, O.A., 2002. "An Analysis of Production Objectives of Small-Scale Rural Farming Households in Kwara State, Nigeria," Journal of Rural Development/Nongchon-Gyeongje, Korea Rural Economic Institute, vol. 25(4), December.

[3] Agamuthu, P. Challenges and opportunities in Agrowaste management: An Asian perspective.
Inaugural meeting of First Regional 3R Forum in Asia 11 -12 Nov., Tokyo, Japan. 2009

[4] Abdulkadir, S. A., Dodo, S. M., Jahun, B., Malgwi, G. S., & Vanke, I. (2020). Design and Construction of an Agricultural Waste-Shredding Machine. ARID ZONE JOURNAL OF ENGINEERING, TECHNOLOGY AND ENVIRONMENT, 16(3), 519-530. Retrieved from https://azojete.com.ng/index.php/azojete/article/view/340

DOI: 10.31695/IJASRE.2023.9.6.4

[5] Mahadev, B. Mohammed, Adil. Abhishek, Y K. Manish, K. And Amith, A. 2020 Design and Fabrication of Agricultural Waste Shredder Machine. HBPR PUBLICATION Advancement in Mechanical Engineering and Technology Vol. 3 (1) Pg 1-8

[6] Joseph Y. Ko.,"Paper Shredding Device",U.S.Patent 6390397B1, 2002.

[7] Ming H. Ho.,2006 "Review and analysis of performance and productivity of equipments.

http://citeseerx.ist.psu.edu>document

[8] Fauzia, S. Harshad, P. Swapnil, R. Omkar, W. and Swapnil, T. 2017 Design and Fabrication of Paper Shredder Machine. International Journal of Scientific & Engineering Research, Volume 8, Issue 3, March-2017 ISSN 2229-5518.

[9] Shigley, J. E. (1986). Mechanical Engineering Design. S.I (metric) ed. New York, USA: McGraw-Hill.

[10] Shigley, JE., and Mischke, CR. 2005. Mechanical Engineering Design: In SI Units (6th ed.). New Delhi: McGraw-Hill.

[11] Kgurmi R. and Gupta J (2005). A text book of machine design. India:Eurasia Publishing House

[12] Khurmi, R., and Gupta, J. 2006. Theory of Machine revised edition. New Delhi, India: S. Chand.

[13] Hall, SS., Mitchell, LD. and George, E. 1980. Mechanical Design: Mc.Graw-Hill. New YorkUnited States..

DOI: 10.31695/IJASRE.2023.9.6.4