International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 02 Feb 2024, pp: 153-163 www.ijaem.net ISSN: 2395-5252

Development and performance evaluation of a combined milling-mixing machine for use in semi-automated briquette processing plant

David Segun Ukanah[1], Olumide AyodejiOlufumi[2] Emmanuel Ankama Idau[3]

[1]*Department of Mechanical Engineering, Federal University of Technology, Akure, Nigeria.*
[2]*Department of Mechanical Engineering, Federal University of Technology, Akure, Nigeria.*
[3]*Department of Mechanical Engineering, Federal University of Technology, Akure, Nigeria.*
Corresponding Author: David Segun Ukanah

Date of Submission: 10-02-2024 Date of Acceptance: 17-02-2024

ABSTRACT:This research endeavors to delineate the conceptualization, construction, and performance assessment of an integrated biomass milling-mixing apparatus, tailored for implementation in a briquette production facility. The procedural culmination substantiates the successful design and fabrication of the machine, demonstrating seamless adherence to its designated operational parameters. The experimental substrate for assessing machine performance comprises desiccated sugarcane bagasse, with local starch employed as the binding agent in the amalgamation of milled sugarcane bagasse.

Evaluation of the milling machine's performance reveals its adeptness in handling varying quantities of dried sugarcane bagasse (300g, 400g, 500g, and 600g) within uniform time constraints of 20 minutes for each feed. The results indicate complete milling for all specified amounts, with the highest percentage output achieved at 600g, suggesting enhanced efficacy when the machine is furnished with a judicious quantity of sugarcane biomass. Furthermore, the milled sugarcane bagasse exhibits an average particle size of 3mm, and subsequent fine particle outputs of 285g, 387g, 489g, and 590g, meticulously measured with a weighing pan.

Machine efficiencies, quantified at each milled ware, register commendable rates of 95%, 96.75%, 97.80%, and 99.33%. Notably, the machine's mixing functionality yields a homogeneous binding of bagasse and starch, attaining a bonding strength of 4.5 MPa ascribed to the adhesive interplay between the starch binder and milled bagasse. The amalgamation of biomass milling and mixing into a singular unit for biomass production is conclusively validated as an immensely effective and efficient technological paradigm, poised for adoption in mechanical engineering endeavors, particularly within the biomass production domain.

KEYWORDS: Biomass, Milling, Briquette,Sugarcane, Machine, Production.

I. INTRODUCTION

A briquetting machine is a compaction technology used to compress various materials into briquettes, which are solid blocks with a defined shape and size. The process involves applying high pressure to the materials, forcing them into the nip of two counter-rotating wheels or using other mechanisms, such as screw or gravity feeders [1].

A briquette is a compressed block of coal dust or other combustible biomass material that is used as fuel and kindling to start a fire. It is typically made from materials such as coal dust, charcoal, sawdust, wood chips, peat, or paper. The purpose of a briquette is to provide a convenient and efficient energy source, especially for industrial used, homes and offices [2].

An automated briquetting machine is a type of briquette machine that is designed to operate with some degree of automation. It is capable of producing briquettes without the need for extensive manual intervention. The level of automation can vary, ranging from fully automatic machines to those that offer semi-automatic options. Automated briquetting machines utilize various mechanisms to achieve this compression. For instance, hydraulic-type machines rely on a hydraulic pump station to supply high pressure for compression; piston-type machines use the rotary power of a mechanical device or the thrust of a hydraulic cylinder to generate the pressing force, and roller press machines work with two close rotating rollers to press the material [3].

An automated briquetting machine is a type of briquette machine that is designed to operate with some degree of automation. It is capable of producing briquettes without the need for extensive manual intervention. The level of automation can vary, ranging from fully automatic machines to those that offer semi-automatic options. Automated briquetting machines utilize various mechanisms to achieve this compression. For instance, hydraulic-type machines rely on a hydraulic pump station to supply high pressure for compression; piston-type machines use the rotary power of a mechanical device or the thrust of a hydraulic cylinder to generate the pressing force, and roller press machines work with two close rotating rollers to press the material [3].

Semi-automated briquetting machines unlike fully automated machines, which require minimal human intervention, usually involve manual loading of the raw materials and control of the briquetting process. Typically, a semi-automated briquetting machine consists of a feeding hopper or conveyor system to introduce the biomass material into the machine, a compression chamber where the material is compressed under high pressure, and a hydraulic or mechanical system to apply the pressure. The machine may also have a heating element or a binder mixing system, depending on the type of briquettes being produced [4].

A biomass milling machine used in a briquetting plant is a specialized piece of equipment designed to transform raw biomass into finely ground particles suitable for briquette production. It ensures that the biomass meets the necessary specifications for efficient compaction and high-quality briquettes. Major parts of the biomass milling machine are the hopper, milling chamber, and milling shaft. [5]. Careful design, integration with other process components of the briquetting plant, and attention to particle size control and moisture management are essential factors in creating an effective and efficient biomass milling machine for use in briquetting operations [6]. A biomass milling machine designed for use in a briquetting plant plays a critical role in preparing biomass, for efficient conversion into briquettes.The biomass milling machine is engineered to process raw biomass into finely ground particles, optimizing its suitability for briquetting while considering factors such as particle size, moisture content, and uniformity.[6]

After milling to the appropriate particle size and moisture level, the biomass can be fed directly into the briquetting machine for compaction. The uniformity of the ground biomass contributes to consistent briquette quality and optimal combustion characteristics.A mixing machine is a machine used for blending biomass and binder. It is an industrial device specifically designed to combine biomass material, with a binder substance in a uniform and consistent manner. Its major parts are the mixing chamber, hopper, and mixing shaft.

A biomass and binder mixing machine is an essential component of the briquetting plant, responsible for achieving a uniform and cohesive mixture that is ideal for briquette production. Through proper design, selection of mixing elements, binder dispensing systems, and control mechanisms, the machine ensures that biomass and binder are blended efficiently. This results in high-quality briquettes with consistent composition and enhanced combustion properties, contributing to the overall success of the briquetting process and its environmental and energy-related benefits [7].

A mixing machine designed for blending biomass and binder serves a crucial role in the briquetting process by homogeneously combining biomass, a fibrous biomass material, with a binder to create a cohesive mixture. This mixture is then fed into a briquetting machine to produce compact and energy-dense briquettes. The biomass and binder mixing machine ensures proper dispersion of the binder throughout the biomass, optimizing the briquette quality, structural integrity, and combustion characteristics [7].

The development of a combined milling-mixing machine for use in a semi-automated briquette processing plant refers to the process of designing, engineering, and constructing a well organize system involving a combination of the two machines into a unit[8]. It involves various stages, including conceptualization, research, design, prototyping, testing, and refinement, with the ultimate goal of creating a functional and reliable machine that meets the project objectives[8].

During the development process, the desired functionality and requirements of the combined machine will be translated into technical specifications and designs using computer-aided design (CAD) software, conduct simulations, and perform calculations to ensure the components of both machines, mechanisms, and systems work together harmoniously. The Performance evaluation of the combined miller and mixer involves assessing its operational effectiveness, efficiency, reliability, and overall quality of output. It is a systematic process of measuring and analyzing the machine's performance against established criteria or benchmarks. The evaluation aims to determine how well the machine performs its intended functions and whether it meets the desired performance standards [9].

II. LITERATURE REVIEW OF MECHANICAL METHODS OF PRE-PROCESSING BIOMASS

[21] reviewed the mechanical pretreatment of [22] biomass for bio-fuels and bio-products. The author discussed the different mechanical pretreatment methods, their advantages and disadvantages, and their effects on the physical and chemical properties of the biomass. The results showed that mechanical pretreatment is an effective method for improving the accessibility of cellulose and hemicellulose in [22] biomass.

[23] reviewed the use of milling as a mechanical pre-treatment method for biomass. The authors discussed the effects of milling on the physical and chemical properties of the biomass, as well as its effect on enzymatic hydrolysis. The results showed that milling can improve the accessibility of cellulose and hemicellulose in [22] biomass.

[24] reviewed the use of a screw press as a mechanical pre-treatment method for lignocellulosic biomass. The authors discussed the effects of screw pressing on the physical and chemical properties of the biomass, as well as its effect on enzymatic hydrolysis. The results showed that screw pressing can improve the accessibility of cellulose and hemicellulose in lignocellulosic biomass

[25] carried out a comprehensive review of mechanical pre-treatment methods for enhanced enzymatic hydrolysis of lignocellulosic biomass. The authors discussed various mechanical pre-treatment methods such as milling, extrusion, and compression, and their effects on the physical and chemical properties of the biomass. The results showed that mechanical pre-treatment is an effective method for improving enzymatic hydrolysis efficiency.

[26] reviewed various mechanical pretreatments for enhancing biogas production from lignocellulosic substrates. The authors discuss various mechanical pretreatment methods such as milling, extrusion, and compression, and their effects on biogas production. The results show that mechanical pretreatment is an effective method for enhancing biogas production from lignocellulosic substrates

[27] reviewed various mechanical pretreatments for enhancing bioethanol production from lignocellulosic substrates. The authors discussed various mechanical pretreatment methods such as milling, extrusion, and compression, and their effects on bioethanol production. The results show that mechanical pretreatment is an effective method for enhancing bioethanol production from lignocellulosic substrates.

2.1 GAPS IN THE LITERATURE

The literature reviewed so far, showed that a good amount of work in the area of biomass pre-processing methods. However, there is still a need to improve pre-processing time and efficiency, by the design of combined mechanical devices, incorporated to work together. This work has fill this gap by the design of a combined biomass milling-mixing machine that help in mass production of briquettes to meet the global demand.

III RESEARCH METHODOLOGY

This section outlines the methods and materials applied in the development of the milling-mixing machine as well as the methods used in the performance evaluation of the machine.

3.1 MATERIALS

The development of the milling-mixing machine included the construction and the automation aspects.

The evaluation materials include binding agent (starch) and sugarcane bagasse which have been obtained from sugarcane waste. The fabrication materials for developing the machine, include mild sheet, angle iron, fasteners (bolts and nuts) mechanical power transmission system (pulley, electric motor and power transmission belt). The sizes and specifications of these materials are determined using the outcomes of the design analysis and relevant engineering standards. The materials ware sourced within Akure metropolis.

S/N	PART NAME	FUNCTION	MATERIAL
1	Frame	Forms the main structure of the machine that carries other parts and withstand vibration loads and stresses	Mild Steel
2	Electric motor	Provides the required power needed to rotate the shafts	-
6	Belt	Transmits Power from the electric motor to the machine via pulleys	Leather
9	Milling shaft	Used in the milling machine and has blades along its length to grind the biomass to small fine particles as it rotates	Mild Steel
10	Mixing shaft	Used in the mixer to mix the grinded biomass with binder while it rotates	Mild Steel
12	Pulleys	Rotates the shafts	Mild Steel
13	Hopper	Hopper serves as a means of feeding the biomass material into the machine	Mild Steel

3.2 PROCESSES ADOPTED

The methodology that was adopted for achieving the objectives of this research entails the following

(i) Studying of relevant literature;

(ii) Utilizing data obtained from studied literature and appropriate engineering standards for effective the design analysis;

(iii) Developed conceptual drawings with relevant computer software (SolidWorks);

(iv) Infected amendment to dimension of the machine, for deviations that arise in measurement;

(v) Procurement of materials used results of design analysis and appropriate engineering standards;

(vi) Fabricated the machine as exemplified in the detailed and assembly drawings;

(vii) Mounting of instrumentations and evaluation of the developed machine to ensure its conformity with the set objectives, and

(viii) Compilation of facts/ observations and formulation of the findings, based on outcome of (vii) above

3.3DESIGN CALCULATIONS

The design Calculations was done to determine the specifications and sizes of the parts. These design calculations were carried out using mathematical formulations from relevant literatures.

3.3.1 DESIGN CALCULATIONS FOR THE MILLING MACHINE

3.3.1.1 Calculation of milling pulley diameter and speed for the milling shaft

- Speed of electric motor chosen to drive the machine Ne = 1440 rpm
- Diameter of the electric motor output shaft pulley D_e = 63 mm
- Speed ratio between electric motor output shaft pulley and the milling machine shaft pulley is1:3

Applying the speed ratio equation:

$\frac{N_m}{N_e} = 3 = \frac{D_m}{D_e}$(3.1)

$$\frac{N_m}{N_e} = 3 = \frac{D_m}{63}$$

From which;

$$D_m = 3\ X\ 63 = 189\ mm \approx 200\ mm$$

Also from equation 1,

$$\frac{N_m}{N_e} = \frac{D_m}{D_e} = \frac{1440}{3} = 480\ rpm$$

Speed of the milling shaft N_m = 480 rpm

Velocity of the milling shaft in m/s, v is given as;

$v = \frac{\pi D_m N}{60}$(3.2)

$$v = \frac{\pi\ X\ 0.2\ X\ 480}{60} = 5.03\ m/s$$

3.3.1.2 Calculations for the bagasse feedstock into the milling machine

Highest Mass of Bagasse feedstock = 0.6 kg

Assuming feed rate of 3 per hour, Mass of bagasse feedstock fed per hour = 3 X 0.6 = 1.8 kg/hr

Weight of feedstock fed per hour = $\frac{1{,}8\ X\ 9.81}{1000}$

$$= 0.01765\ kN/h$$

3.3.1.3 Calculations for the Outer diameter of the milling machine shaft

Weight of feedstock fed per hour,

$Q = 3.6 \times q \times v$ (3.3)

Where Q = 0.01765 kN/h, q is the hourly capacity per second along the milling shaft (kg m/s), and v is the velocity of the milling shaft = 5.03 m/s.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 02 Feb 2024, pp: 153-163 www.ijaem.net ISSN: 2395-5252

From equation 3, $q = \frac{Q}{3.6 X v} = \frac{0.01765}{3.6 X v}$
$= 9.75 X 10^{-4} kgm/s$
Also, hourly capacity per second;
$A \times v \times \rho \times g \times l \ kgm/s$ (3.4)
Where A is the cross-sectional area of the milling shaft in m^2, v is the velocity of the milling shaft = 5.03 m/s, ρ is the density of the bagasse feedstock = 100 kg/m^3, g is the acceleration due to gravity = 9.81 m/s^2, and l is the length of the milling shaft = 400 mm.
Cross sectional area of the milling shaft is given as;

$$A = \frac{\pi}{4} X \left(d^2 - {d_m}^2\right) m^2$$

Where d and d_m are the outer and inner diameters of the milling shaft respectively, d_m = 25 mm
From equation 3.4;
$q = \frac{\pi}{4} X (d^2 - 0.025^2) X 100 X 9.81 X 0.4 = 9.75 X 10^{-4}$
From which the outer diameter of the shaft, d = 220 mm.

3.3.1.4 Calculations for the total force acting on the milling shaft F_T
Fore due to weight of the bagasse fed into the milling machine
F_g= m X g (3.6)
Where m is the mass of the bagasse = 0.6 kg, and g is acceleration due to gravity.

$$F_g = 0.6 X 9.81 = 5.886 N$$

Centripetal force acting on the shaft:
$F_c = \frac{mv^2}{r} \ N$ (3.7)
Where v is the shaft velocity = 5.03 m/s, and r is the radius of the shaft pulley = 0.1 m

$$F_c = \frac{0.6 X 5.03^2}{0.1} = 151.8 N$$

Frictional force acting on the milling shaft, F_f is given as;
$F_f = \mu R$ (3.8)
Where μ is the dynamic co-efficient of friction = 0.4463, and R is the Force reaction = 151.8 N
From equation 8; $F_f = 0.4463 X 151.8$
$= 67.75 N$
Total force acting on the shaft, F_T is given as;
$F_T = F_g + F_c + F_F$(3.9)
From which F_T = 5.886 + 151.8 + 67.75 = 225.43 N

3.3.1.5 Calculations for the Total Power required for driving the Milling machine P_T
Conveying power of the milling machine, P_c is given as;
$P_C = 4.5 \times q \times l \times \rho \times g$(3.10)
From which

$$P_C = 4.5 X 9.75 X 10^{-4} X 0.4 X 100 X 9.81 = 1.72 kW$$

Milling Power, P_g is given as;
$P_g = T X \omega$(3.11)
Where T is the shaft Torque = F_T X r = 225.43 X 0.1 = 22.543 Nm, and
$\omega = \frac{2 X \pi X N}{60} \ rad/s$ (3.13)
From equation 3.11, Milling Power
$P_g = \frac{2 X \pi X N_m X T}{60}$(3.13)

$$\frac{2 X \pi X 480 X 22.543}{60} = 1.13 kW$$

Total Power required for driving the Milling machine P_T is given as;
$P_T = P_c + P_g$(3.14)
P_T = 1.72 + 1.13 = 2.85 kW
Horse power required = $\frac{1.13}{0.75} = 1.517$
$\approx 2.0 hp$

3.3.1.6 Calculations for the Length of Belt required for driving the Milling machine (L)
The Length of the Belt, L is given as;
$L = \frac{\pi}{2} X (D_m + D_e) + 2C + \frac{(D_m - D_e)^2}{4 X C}$ (3.15)
Where C is the centre distance between motor pulley and milling shaft pulley,
Taking C =450 mm,

$$L = \frac{\pi}{2} \times (200 + 63) + (2 X 450) + \frac{(200 - 63)^2}{4 X 450} = 1323.6 mm$$

L = 1.3236 m

3.3.2 DESIGN CALCULATIONS FOR THE MIXING MACHINE
Mass of bagasse m_1 = 0.6 kg
Density of bagasse ρ_1 = 100 kg/m^3
Density of Starch (Binder),ρ_2 = 1050 kg/m^3
Percentage of binding is between 6 – 7.5%
For 0.6kg of bagasse, Quantity of binder required is given as $\frac{0.6 X 7.5}{100} = 0.045 kg$
Volume of Binder required ;
$V_b = \frac{m_b}{\rho_2}$(3.16)

$$\frac{0.045}{1050} = 4.29 \times 10^{-5} m^3$$

Volume of the Bagasse-Binder mixture
$V_T = V_1 + V_b$ (3.17)
Where V_1 is the volume of bagasse, without starch binder in m^3
V_T = 3 X (0.06 + 4.29 X 10^{-5})
= 0.0181287 m^3
Density of the mixed feedstock is given as
$\rho = \frac{m_1 + m_b}{V_T}$ (3.18)

$$\rho = \frac{3(0.6 + 0.045)}{0.0181287} = 106.73686 kg/m^3$$

Mass of the mixed feedstock is given as;

$$m_T = \rho_T \ X \ V_T$$

$$106.73686 \text{ X } 0.0181287 = 1.935 \text{ kg}$$

Weight of the feedstock supplied to the Mixer is given as;

$Q = m_T \text{ X } g$ (3.19)

$$= 1935 \text{ X } 9.81$$

$$= 1.89823 \text{ X } 10^{-2} \text{ kN/hr}$$

From equation 3.3, Weight of feedstock fed per hour,

$Q = 3.6 \text{ X } q \text{ X } v = 1.89823 \text{ X } 10^{-2} \text{kN/hr}$

Taking the rotational speed of the mixing shaft,

$N_s = 6$ rpm

$$\text{Velocity } v = \frac{\pi \text{ X } D \text{ X } N}{60} = \frac{\pi \text{ X } D \text{ X } 0.6}{60}$$

$$= 0.1\pi D$$

Taking the diameter of the mixer shaft pulley

D = 152.4 mm,

$$\text{Velocity } v = 0.1 \text{ X } \pi \text{ X } 152.4 \text{ X } 10^{-3}$$

$$= 0.04788 \text{ m/s}$$

From equation 3.3, the hourly capacity per second

$$q = \frac{Q}{3.6 \text{ X } v} = \frac{1.89823 \text{ X } 10^{-3}}{3.6 \text{ X } 0.04788}$$

q= 0.01737 kgm/s.m,

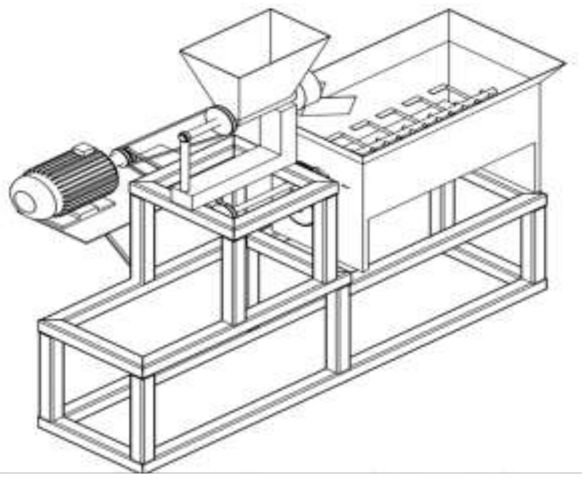


Figure 3.1 Isometric view of the Biomass Milling-Mixing machine

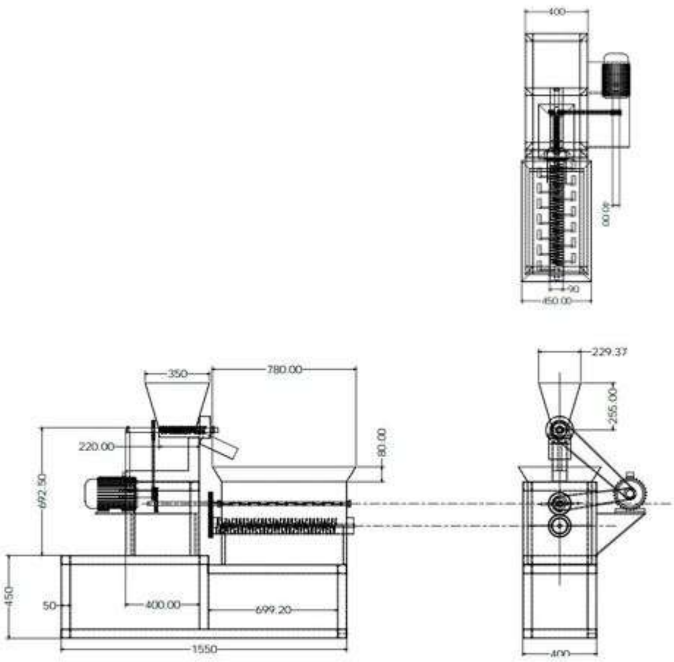
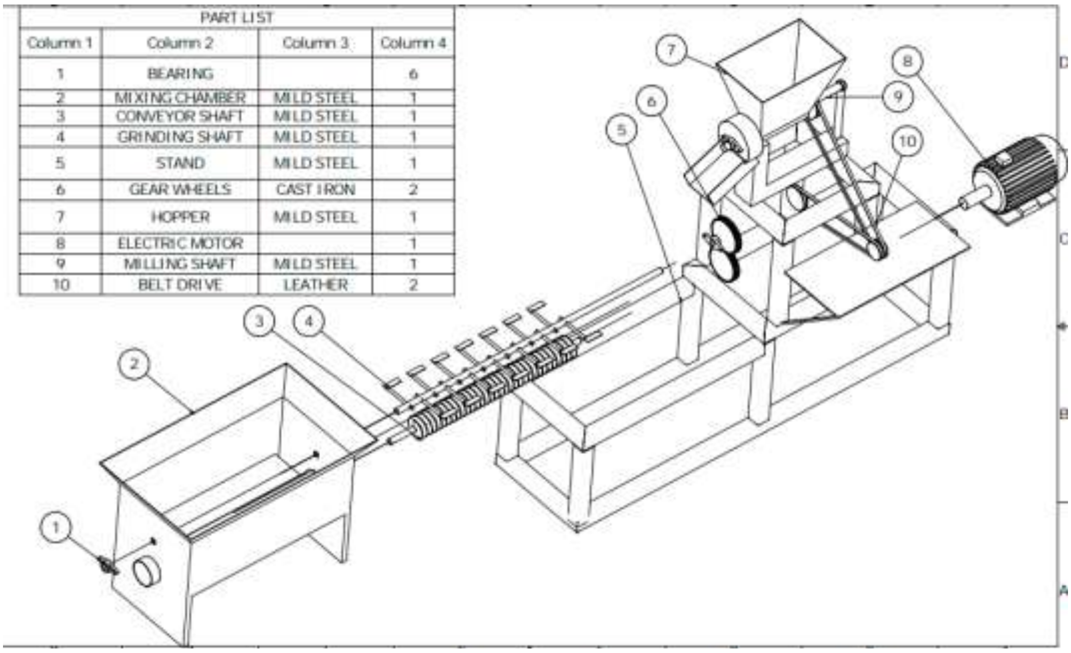


Figure 3.2: Orthographic views of the Biomass Milling-Mixing machine

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 02 Feb 2024, pp: 153-163 www.ijaem.net ISSN: 2395-5252



PART LIST			
Column 1	Column 2	Column 3	Column 4
1	BEARING		6
2	MIXING CHAMBER	MILD STEEL	1
3	CONVEYOR SHAFT	MILD STEEL	1
4	GRINDING SHAFT	MILD STEEL	1
5	STAND	MILD STEEL	1
6	GEAR WHEELS	CAST IRON	2
7	HOPPER	MILD STEEL	1
8	ELECTRIC MOTOR		1
9	MILLING SHAFT	MILD STEEL	1
10	BELT DRIVE	LEATHER	2

Figure 3.3: Exploded view of the Biomass Milling-Mixing machine

Figure 3.4 Picture of the milling-mixing machine during assembly for testing

3.4 OPERATION PROCESS

The briquetting machine operation starts with the feeding of loose Bagasse biomass by the operator into the hopper of the milling machine. The electric motor for the milling machine is powered ON. At the milling machine, the bagasse is milled into small fine particles. Afterwards, it is fed direct into the mixer by gravitational force since the outlet of the milling machine was design in such a way that the milled bagasse enter into the mixer, where the particles of the bagasse evenly mixed with a binder material (Starch). The mixture produced at the mixer then be conveyed to the briquetting machine, where the compaction process takes place.

3.5 PERFORMANCE EVALUATION

3.5.1 PERFORMANCE EVALUATION OF THE MILLING MACHINE

With the shaft of the biomass milling

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 02 Feb 2024, pp: 153-163 www.ijaem.net ISSN: 2395-5252

machine rotating at 480rpm, and powered by a 2hp electric motor, 600grams of dried bagasse were fed into the hopper of the machine, and milled for 20minutes. The milled bagasse were collected into a porous sack and weighed. Also the milled bagasse was also passed through a screen, in order to determine the measure of fineness of the particles.
Efficiency of the milling machine $ή_1$ is calculated by;

$$ή_1 = \frac{\text{Mass of bagasse after milling}}{\text{Mass of bagasse fed into the machine}} \times 100 \quad (3.20)$$

3.5.2 PERFORMANCE EVALUATION OF THE MIXING MACHINE

The milled bagasse is conveyed into the mixer, where it is mixed with 30g of starch by the mixing shaft. This process is done for 30minutes. The mixture of biomass and starch coming out from the mixer is weighed, and observed for about 10 minutes in order to determine the bond strength of the mixture

IV. RESULTS AND DISCUSSION

4.1 RESULTS

The results obtained from the performance evaluation for the milling machine and the mixing machine is presented in this section.

4.1.1 RESULTS FOR THE MILLING MACHINE

The result for the performance test carried out on the milling machine is shown as follows;

1. Mass of milled bagasse obtained after 20 minutes of milling without mixture for each fed.
2. Average particle size of milled bagasse = 3mm
3. Time taken for milling = 20minutes
4. Efficiency of the milling machine calculated from equation 4.2 as follows;

$$ή_1 = \frac{\textbf{Mass of bagasse after milled}}{\textbf{Mass of bagasse fed into the machine}} \times \mathbf{100}$$

	A	B	C	D
Mass of bagasse fed before milled (g)	300	400	500	600
Mass of result obtained after milled (g)	285	387	489	590
Efficiency of each output (%)	95.00	96,75	97.80	99.33
Average particle sizes (mm)	3	3	3	3

Table 4.1 Results obtained

Figure 4.1 bagasse particles before milling

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 02 Feb 2024, pp: 153-163 www.ijaem.net ISSN: 2395-5252

Figure 4.2bagasse particlesafter milling

4.1.2 RESULTS FOR THE MIXING MACHINE
The result for the performance test carried out on the mixing machine is shown as follows;
1. Mass of starch before used = 35 g
2. Mass of highest milled sugarcane bagasse before mixture = 590 g
3. Mass of bonded mixture after mixing = 620 g
4. Mass of lost starch mixed with milled bagasse = 5g
The results obtained shows that the machine is well design, fabricated, since small percentage of the starch and milled bagasse was lost after weighing the mixture.

Figure 4.3 binder (starch) used for the mixing process

Figure 4.4 bagasse-starch mixture after the mixing process

4.2 DISCUSSION

The milling-mixing machine powered by a 2hp electric motor, and a higher milling efficiency of 99.33%, was fabricated, the output bagasse was weighed and the efficiency of the machines were recorded and showed in a tabular form, the machine was discovered to be dust free after milling. A uniform mixture of starch and bagasse was achieved after the mixing, with a good degree of uniformity. During the test, it was observed that the milling machine required continuous feeding of dried bagasse for best result.

From the uniformity observed, it implies that the bagasse has a good degree of adhesion with the starch. Furthermore, the average grain size of 3mm after milling implies that the milled bagasse is of very fine particle size, which when bonded with the starch, did not loosed or allowance air gaps that can cause breakage.

V CONTRIBUTION OF RESEARCH TO KNOWLEDGE

This project work adds value to the design process and functionality performance of briquetting machines, by the incorporation of a combined milling-mixing machine.

The project also adds to knowledge, the methodology of how to successfully obtain a mixture of starch and milled bagasse for the purpose of compaction and storage for future use as biomass in energy generation that is useful in industries, homes and offices

VI CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

6.1 CONCLUSION

The milling-mixing machine was

successfully designed, fabricated, and tested. It was found to have a milling efficiency of 99.33 %. Also, the average particle size of the milled bagasse was 3mm. The mixing had a very high degree of uniformity. Thus the combined milling-mixing machine when operated within the designed operating parameters will successfully and efficiently mill the biomass fed into it, and mix it with a binder to achieve high uniformity. This ability combined with its capacity to carry out milling and mixing simultaneously, makes it more modified than the existing designs.

6.2 RECOMMENDATIONS FOR FUTURE RESEARCH

1. Future research can be carried into finding other substances that can be used as a binder, which is more cheaper and easily found, that can serve as a replacement instead of starch, in order to obtain a stronger binding of the biomass together, in such a way that the binder will not reduce the energy calorific value of the biomass.
2. A more compact and efficient design of a combined biomass milling-mixing machine can be achieved with more research.
3. Inclusion of electronic control and safety systems into the operation process of the machine, which will enable smooth and safe operation

REFERENCES

[1]. Battle, T., Srivastava, U., Kopfle, J., Hunter, R. and McClelland, J. (2014)"The direct reduction of iron".A Treatise on process metallurgy (pp. 89-176).Elsevier.
[2]. Lubwama, M., Yiga, V. A. (2018)."Characteristics of briquettes developed from rice and coffee husks for domestic cooking applications in Uganda". Renewable energy, 118, 43-55.
[3]. Ngusale, G. K., Luo, Y., Kiplagat, J. K. (2014). "Briquette making in Kenya: Nairobi and peri-urban areas". Renewable and Sustainable Energy Reviews, 40, 749-759.
[4]. Grover, P. D., and Mishra, S. K. (1996). "Biomass briquetting: technology and practices (Vol. 46)". Bangkok, Thailand: Food and Agriculture Organization of the United Nations.
[5]. HarshalBadule, Harish Hedau, DipanshuNandgave, AkshayBarapatre, VinodP.Sakhare. (2018); Design and Development of Biomass Briquetting Machine with Grinding and Blending Unit Department of Mechanical Engineering, GNIT Nagpur, Maharashtra, India.
[6]. Manjunath K S, Omprakash M, Niranjan Pangeni, BiradarHanumant. (2018);Design and Fabrication of Briquetting Machine for Solid Waste. Mechanical Engineering, Bangalore Technological Institute, Bangalore , India-35. Volume – 03, Issue – 05, May 2018, PP – 61-66
[7]. Narzary, A., Chauhan, R., & Das, A. K. (2020).Briquette Making Using Waste Biomass and Analysis of Its Properties. In Recent Developments in Waste Management: Select Proceedings of Recycle 2018 (pp. 33-43). Springer Singapore.
[8]. Kpalo, S. Y., Zainuddin, M. F., Manaf, L. A., &Roslan, A. M. (2020).A review of technical and economic aspects of biomass briquetting.Sustainability, 12(11), 4609.
[9]. Pelumi, I. P., Tobiloba, O., Wallace, O., Oluwatoba, O., Akanni, A. A., Oluwole, A. O., & Sola, O. T. (2019). Performance evaluation of briquette produced from a designed and fabricated piston-type briquetting machine. International Journal of Engineering Research and Technology, 12(8), 1227-1238.
[10]. Sharma, M. K., Priyank, G., & Sharma, N. (2015)."Biomass briquette production: a propagation of non-convention technology and future of pollution free thermal energy sources". American Journal of Engineering Research (AJER), 4(02), 44-50.
[11]. Raju, C. A., Jyothi, K. R., Satya, M., &Praveena, U. (2014).Studies on development of fuel briquettes for household and industrial purpose. International Journal of Research in Engineering and Technology, 3(2), 54-63.
[12]. Eriksson, S., & Prior, M. (1990). "The briquetting of agricultural wastes for fuel".Food and Agriculture Organization of the United Nations.
[13]. RavinaSanap.,Nalawade, M., Shende, J., &Patil, P. (2016)."Automatic screw press briquette making machine". International Journal of Novel Research in Electrical and Mechanical Engineering, 3(1), 19-23.
[14]. InegbeG18431620 dion and Akilaki (2022), F. and Francis-Akilaki, T.I., (2022)."Design and Fabrication of a Briquetting Machine". Journal of Energy Technology and Environment, 4(1), pp.11-20.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 02 Feb 2024, pp: 153-163 www.ijaem.net ISSN: 2395-5252

[15]. Ikubanni, P. P., Agboola, O. O., Olabamiji, T. S., Adediran, A. A., Anisere, T., &Oladimeji, S. (2020, February).“Development and performance assessment of piston-type briquetting machine”. In IOP Conference Series: Earth and Environmental Science (Vol. 445, No. 1, p. 012005). IOP Publishing.
[16]. Marreiro, H.M., Peruchi, R.S., Lopes, R.M., Andersen, S.L., Eliziário, S.A. and Rotella Junior, P (2021). “Empirical studies on biomass briquette production: A literature review”. Energies, 14(24), p.8320.
[17]. Ogundipe, O.B., Nnodim, C.T., Oladimeji, O.S., Agboola, B.D., Adeleke, A.A., Ikubanni, P.P. and Agboola, O.O., (2021). “Development and Performance Evaluation of a Manual Briquetting Machine for Biofuel Production”. Petroleum and Coal, 63(2), pp.509-516.
[18]. Okwu, M.O. and Samuel, O.D., (2018). “Adapted hyacinth briquetting machine for mass production of briquettes”. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 40(23), pp.2853-2866.
[19]. Gatmaitan, R.A., Guanlao, T.J., Guting, R.J., Janairo, C.M. and Chua, A., (2013). “Development of an Automated Briquetting Machine” .In DLSU Research Congress (pp. 1-4).
[20]. Yambot, A., Casano, L., Mina, R., Yu, K. and Chua, A., (2016). “Automated screw type briquetting machine as a small business venture”. International Journal of Automation and Smart Technology, 6(4), p.184.
[21]. Banerjee, N. (2023). Biomass to energy an analysis of current technologies, prospects, and challenges. Bio-Energy Research, 16(2), 683-716.
[22]. Mechanical pretreatments of lignocellulosic biomass: towards facile and environmentally sound technologies for biofuels production. Rsc Advances, 4(89), 48109-48127.
[23]. Barakat, A., Mayer-Laigle, C., Solhy, A., Arancon, R. A., De Vries, H., &Luque, R. (2014).
[24]. Tabil, L., Adapa, P., &Kashaninejad, M. (2011). Biomass feedstock pre-processing-part 1: pre-treatment. Biofuel’s engineering process technology, 18, 411-439.
[25]. Galbe, M., &Wallberg, O. (2019). Pretreatment for biorefineries: a review of common methods for efficient utilisation of lignocellulosic materials. Biotechnology for biofuels, 12, 1-26
[26]. Fang, S., Ping, L., Yang, Z., & Mao, J. (2011, May).A review of different pretreatment techniques for enhancing biogas production.In 2011 International Conference on Materials for Renewable Energy & Environment (Vol. 1, pp. 263-266).IEEE.
[27]. Alvira, P., Tomás-Pejó, E., Ballesteros, M., & Negro, M. J. (2010). Pretreatment technologies for an efficient bioethanol production process based on enzymatic hydrolysis: a review. Bioresource technology, 101(13), 4851-4861.