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Design and Fabrication of an Improved Briquette Making Machine

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Abstract: *This paper presents design and fabrication of an improved briquette making machine. Due to the increasing global demand for energy, coupled with the depletion of fossil fuels and environmental concerns, briquette, a readily available resource, offers a potential solution. Briquetting coal into compact, energy-efficient forms is a promising approach, but its widespread adoption is hindered by the lack of simple, affordable, and energy-efficient briquette-making machines. To fully realize the potential of coal briquetting, there is a pressing need for innovative, low-cost, and energy-efficient briquette-making machines that can produce high-quality briquettes. As a result, this study aimed to design and fabricate an improved briquette making machine to produce briquettes for efficient energy generation.*

Keywords: *Briquette machine; Briquette; Energy source; Coal.*

1. Introduction

Nigeria faces serious energy challenges in its immediate future due the dependence on oil and natural gas given the rise of consumption rate and urban population explosion where half a billion people will be added by 2040 (Lubwama, et al., 2022). Energy demand in Africa grows twice as fast as the global average. Africa's contribution to global energy-related carbon dioxide (CO_2) emissions stands at just 2% is extremely low, but the content is disproportionately affected by its impacts. In West Africa, countries such as Nigeria, Ghana, and Cote d'Ivoire have made remarkable progress in providing modern energy services to millions over the past 5 years. Nonetheless, much remains to be done to deliver universal access to electricity and to expand access to clean cooking, where progress is being outpaced by population growth (Sunnu, et al., 2023).

Access to clean cooking facilities means access to (and primary use of) modern fuels and technologies, including natural gas, liquefied petroleum gas (LPG), electricity, bioethanol and biogas, or improved raw coal cook stoves which deliver significant improvements compared with basic raw coal cook stoves and three-stone fires traditionally used in some developing countries. Cooking fuels in Nigeria are mainly dominated by fuelwood (in rural areas) and charcoal (in urban areas). More than 70% of the population in Africa, around 900 million people, lack access to clean cooking. Approximately 80 to 90% of urban households in the region depend on unsustainable sources of charcoal for cooking and heating (Mwampamba, et al., 2013). The resulting household air pollution from traditional cooking fuels is responsible for approximately 500,000 premature deaths a year. Fuel wood and charcoal also contribute to forest depletion resulting from unsustainable harvesting of fuel wood, as well as imposing a considerable burden and loss of productive time, mostly on women (IEA, 2022). Alternatives and possible solutions to this status quo have seen the pioneering of briquettes developed from raw coal.

Briquettes are solid fuels made from carbonized raw coal or densified raw coal that is subsequently carbonized. Briquetting is the process of converting low–bulk density raw coal into high-density and energy-concentrated fuel (Lubwama & Yiga, 2017). Utilization of raw coal as a primary source of raw material in the development of briquettes as alternative cooking fuels presents a significant opportunity to develop sustainable cooking fuels, while at the same time handling the waste management and environmental challenge that arises when these raw coals are left to rot or burned in open fields. Briquetting of raw coal provides a cooking fuel in a sustainable manner and provides an alternative to fuelwood and charcoal. Briquetting can be carried out using high compaction pressure or low compaction pressure (Lubwama & Yiga, 2018; Lubwama, et al., 2020). High compaction pressure is associated with high costs required to ensure densification of the loose raw coal. A more commonly used approach in Africa is briquetting under low pressure after the raw coal have been carbonized and then mixed with a binder prior to densification to enhance cohesion (Yank, et al., 2016). Low-pressure densification costs much less and easily utilize locally available materials making it ideal for local farmers, youth, and women groups in Africa.

Briquetting coal into compact, energy-efficient forms presents a viable solution, but the lack of simple, cost-effective, and zero-energy requirement machine hinders its widespread adoption. Existing briquette-making technologies often require significant capital investment, complex operations, and external energy sources, limiting their scalability and accessibility. To fully harness the potential of coal briquetting with better combustion efficiency, there is a critical need to design and fabricate improved briquette-making machine that is simple, affordable, and capable of producing high-quality briquettes without relying on external energy sources.

2. Materials and Methods

The materials used for construction include mild steel, alloyed steel, and structural steel. The following equipment were used during the fabrication process, shown in the Table 2.1.

Table 2.1: Equipment used for the fabrication of the briquette machine

S/N	Tool	Manufacturer	Model Number	Quantity
1	Measuring tool (tri-square rule)	Mitutoya	500-510	1
2	Scriber	Starrett	785	1
3	Vernier Caliper	Mitutoya	500-520	1
4	Drilling Machine	Makita	DP001	1
5	Arc Welding Machine	Lincoln Electri	Pro-Wed 250	1
6	Grinding Machine	Bosch	GWS 2500	1

2.1 Design and Fabrication of the Briquette Machine

The design and fabrication of the briquette machine involves various design equations, autocad design, welding and fabrication processes.

2.1.1 Design Equations

The machine was designed to produce 16 briquettes at a time. The total area on which the pressure act was obtained from Equation 3.1 (O.T. & Mohammed, 2015)

$$A_a = n\frac{\pi d^2}{4} \tag{2.1}$$

Where, n is the number of briquettes that is formed at a time and d is the diameter of the moulding die in mm. Some of the parameters were estimated from the Equations 3.2-3.5 (O.T. & Mohammed, 2015) and the parameters for the design are shown in Table 3.2.

$$F = \frac{P}{A} \tag{2.2}$$

$$P = \frac{F}{A} \tag{2.3}$$

$$T = F \tag{2.4}$$

$$T_m = \frac{F}{P \times A} \tag{2.5}$$

Where, F is the force exerted on the plunger in N, P is the pressure exerted on the compression piston in N/cm, T is the tension in N and T_m is the maximum thickness of the base plate in cm.

Table 2.2 presents the key parameters involved in the fabrication on the briquette machine. These parameters include the force exerted on the plunger, the pressure exerted on the plunger and compression piston, the base area of the compression/extrusion piston, the tension exerted by the spring, the projected area, and the maximum thickness of the base plate.

Table 2.2: Parameter values used in the design analysis

Parameter	Values
Force exerted on the plunger	485.5 N
Pressure exerted on the plunger	4.12 MPa
Pressure exerted on compression piston	988.1 MPa
Base area of the compression/extrusion piston	0.000228 m^2
Tension exerted by the spring	328 N
Projected area	0.015 m^2
Maximum thickness of base plate	1.70 mm

A 5-tonne hydraulic jack was used to provide the required pressure to compress the briquettes. The hydraulic jack was sourced as a pre-purchased item. Detailed design drawings were created to specify the dimensions, materials, and components of the briquette machine. The design considered factors such as ease of operation, maintenance, and scalability. Detailed design of the briquette machine is shown in Figure 2.1-2.2. Figure 3.1 shows the front view, top view and side view design of the briquette machine. Figure 3.2 is an isometric view of the designed machine show the 3-D view of the components.

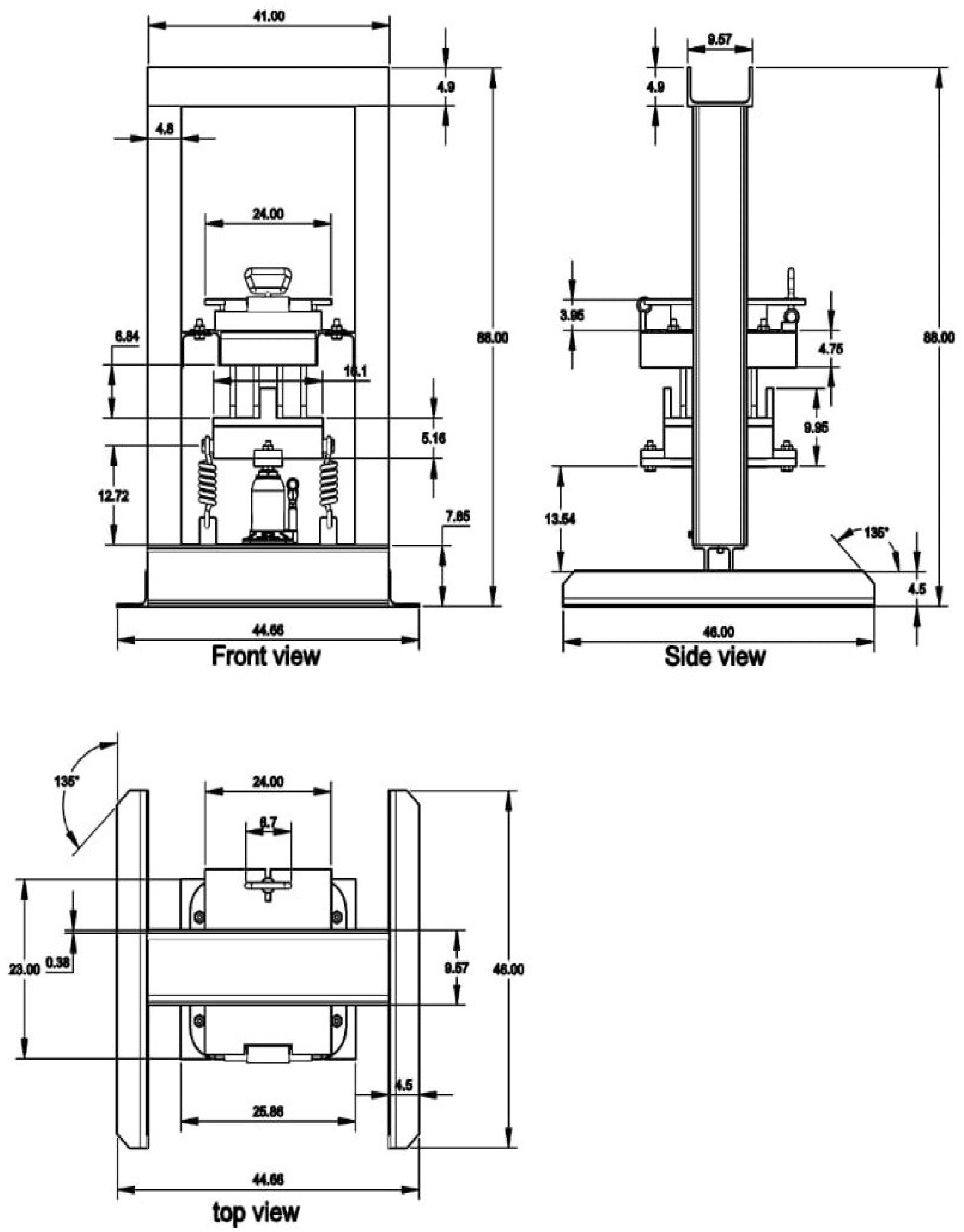

Figure 2.1: View of the design of the briquette machine

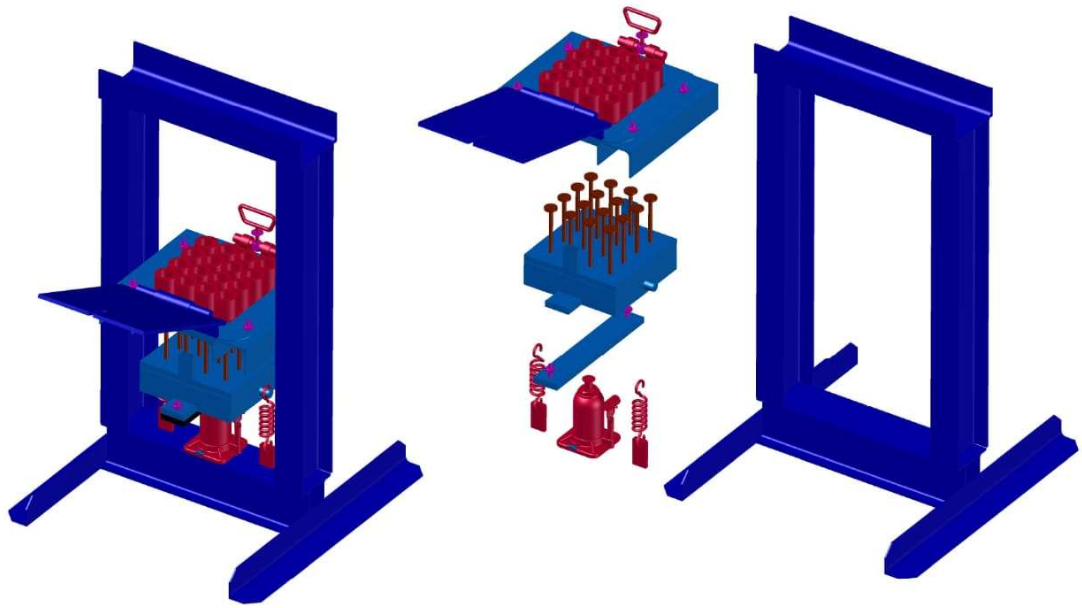

Figure 2.2: Isometric view of the designed briquette machine

2.1.2 Fabrication of briquette machine

This fabrication involved several key steps, including cutting the required materials, joining the components by welding the frame and bolting the base, followed by machining the parts to ensure proper fit and functionality. Finally, the assembly of the components was completed to achieve the final structure. The fabricated briquetting machine is composed of five primary components: the main frame and mould, a helical cylindrical tension spring, a piston rod base plate, and a hydraulic system that includes a fluid tank, cylinders (master and slave), and hydraulic pipes. The mould, located at the lower section of the frame, is constructed from 10 mm thick mild steel with one open end. The hydraulic piston moves downward, applying significant force to compact the material while also aiding in the removal of the compressed briquette from the mould. A cylindrical helical tension spring is employed to retract the compression piston.

The 5-tonne hydraulic jack located beneath the base plate was utilized to raise the plate assembly holding the transmission rods. This action pushes the piston against the mixture inside the dies of the compaction chamber, compacting the material against the machine's lid. The pressure gauge attached to the hydraulic jack provided a reading during the process.

3. Results and Discussion

3.1 Machine Assembly

The fabricated briquetting machine, illustrated in Plate 3.1, is composed of five primary components: the main frame and mould, a helical cylindrical tension spring, a piston rod base plate, and a hydraulic system that includes a fluid tank, cylinders (master and slave), and hydraulic pipes. The mould, located at the lower section of the frame, is constructed from 10 mm thick mild steel with one open end. The hydraulic piston moves downward, applying significant force to compact the material while also aiding in the removal of the compressed briquette from the mould. A cylindrical helical tension spring is employed to retract the compression piston.

Plate 3.1: Fabricated Briquette machine

The 5-tonne hydraulic jack located beneath the base plate was utilized to raise the plate assembly holding the transmission rods. This action pushes the piston against the mixture inside the dies of the compaction chamber, compacting the material against the machine's lid. The pressure gauge attached to the hydraulic jack provided a reading during the process.

4. Conclusion

Based on the study objectives, the following conclusions were drawn: An improved briquetting machine was successfully designed and fabricated, incorporating essential components like a main frame and mold, a helical cylindrical tension spring, a piston rod base plate, and a hydraulic system. The machine exhibited effective operation with comparable mean production times for both coal and charcoal. Furthermore, the machine successfully produced briquettes from both demineralized coal and charcoal, demonstrating consistent weight distribution across the briquettes. This validates the machine's versatility in processing different materials effectively.

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