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DESIGN OF A PEDAL OPERATED BRIQUETTE PRESS

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ABSTRACT

This paper treats the design of a small pedal operated briquette press to produce three (3) briquettes of about 220mm length at a time using agricultural and wood wastes . The small light weight fuel briquette machine was successfully constructed using locally available materials and tested. The machine was able to produce 120 briquettes per hour and it will reduce the cutting down of trees for fuel-wood purposes, thereby preventing deforestation and erosion. Shrinkages were noticed and the final size of the briquette upon drying was observed to be 210 mm x 80 mm x 67 mm. The average true and apparent densities were also found to be 338.2 kg/m^3 and 263.04 kg/m^3 respectively. The effect of the binder content on the combustion potentials of the briquette needs to be investigated further. The product (briquette) obtained from the machine can be used as alternate to fuel-wood in domestic cooking and small-scale industries. The machine will also enable agricultural waste to be removed from the environment, thereby preventing environmental pollution and reducing climate change.

KEYWORDS: waste, briquette, biomass, sustainable development, alternative fuel.

INTRODUCTION

Biomass densification by means of some form of mechanical pressure to reduce the volume of vegetable matter and its conversion to a solid form which is easier to handle and store than the original material, is called briquetting. The briquetting of agro-residues is one sure way of fighting climate change and ensure sustainable development due to the fact that it reduces dependence on fossil fuel, use waste products, as well as it reduces pollution which may have resulted in case of dumping. There are a number of ways which have been developed to solve the problem of how to put the huge volume of wastes from agriculture and agro-processing to some useful purpose? Briquettes can be used as an alternative to fuel-wood as the demand for the latter, especially in the developing countries continue to rise as a result of increasing population. Also the problem of agricultural and municipal waste disposal (i.e. sawdust, rice husk, office and household waste, etc.) is posing challenge to the farmer and the general public as these wastes constitute a nuisance to the environment. Also, more than two billion people globally use biomass for cooking food. Smoke from burning biomass is one of the fourth leading causes of death and disease in the world's poorest countries (WHO 2002).

Many of the developing countries produce huge quantities of agro residues but they are used inefficiently causing extensive pollution to the environment. The major residues are rice husk, coffee husk, coir pith, jute sticks, bagasse, groundnut shells, mustard stalks and cotton stalks. Sawdust, a milling residue is also available in huge quantity. Apart from the problems of transportation, storage, and handling, the direct burning of loose biomass in conventional grates is associated with very low thermal efficiency and widespread air pollution. In the case of rice husk, this amounts to more than 40% of the feed burnt. As a typical example, about 800 tonnes of rice husk ash are generated every day in Ludhiana (Punjab) as a result of burning 2000 tonnes of husk (Erikson and Prior, 1990). Briquetting of the husk could mitigate these pollution problems while at the same time making use of this important industrial/domestic energy resource. Historically, biomass briquetting technology has been developed in two distinct directions, Europe and the United States has pursued and perfected the reciprocating ram/piston press while Japan has independently invented and developed the screw press technology. Although both technologies have their merits and demerits, it is universally accepted that the screw pressed briquettes are far superior to the ram pressed solid briquettes in terms of their storability and combustibility. Worldwide, both technologies are being used for briquetting of sawdust and locally available agro-residues. Although the importance of biomass briquettes as substitute fuel for wood, coal and lignite is well recognized, the numerous failures of briquetting machines in almost all developing countries have inhibited their extensive exploitation. Briquetting technology is yet to get a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. Overcoming the many operational problems associated with this

technology and ensuring the quality of the raw material used are crucial factors in determining its commercial success. In addition to this commercial aspect, the importance of this technology lies in conserving wood, a commodity extensively used in developing countries and leading to the widespread destruction of forests.
Inegbenebor (2002) compressed fibrous agricultural and wood waste materials with suitable adhesive into solid fuel briquettes in a compressing machine, which was designed and constructed for this purpose. Nine samples of fibrous waste materials were prepared into different categories: - Category A (100% saw-dust, 100% rice-husk, 50-50% rice-husk/sawdust using starch as adhesive). Category B (100% saw-dust, 100% rice-husk, 50-50% rice-husk/ saw dust using gum arabic as adhesive) and category C (100% saw-dust, 100% rice husk, 50-50% rice-husk/saw dust using bentonite as adhesive). The solid fuel briquettes in category C had the lowest average moisture content of 9.1%, categories A and B solid fuel briquettes had 10.5% and 13.0%, respectively. Results from a water boiling test (WBT), involving comparison of the burning abilities of the solid fuel briquettes and fire wood of the same quantity (200 grams) in boiling 1.5 litres of water showed that the solid fuel briquettes bound with each of the three adhesives; bentonite, gum arabic and starch; boiled water within a period of 14 to 22 minutes, while firewood did so within a period of 22 to 27 minutes. Aris *et al.* (2007) focused on the development of briquettes from oil palm waste to enhance its utilization as fuel. The reuse of waste material reduces operation costs, negative environmental effects and dependency on conventional fuels. Several aspects of improvement to the physical properties as well as energy content were taken into account in the study. A total of eight tests were conducted for different ratios of shell, fibre and binder mixtures as well as varying the type of binder material used. Varying briquette pressing pressures were also considered in these tests. Results show good physical properties in terms of durability, impact and compressive strength for a 36:54:10 ratio by mass of fibre, shell and waste paper briquette with 5. 7% ash and 5. 24% moisture content. The gross calorific value of 22.4 MJ/kg indicates good energy content of the briquette. The briquette pressing pressure of 159 MPa was used after discovering that it had an outright positive effect on almost all physical and energy components for all combinations tested. Olorunnisola (2007) designed and tested a cylindrical briquette extrusion machine using paper waste and coconut husk. He investigated the effect of mixing ratios on the stability of the produced briquettes. Deiena *et al.* (2004) studied the use of grape must as a binder to obtain activated carbon briquettes of good mechanical and surface properties. Okonkwo *et al.* (2007) examined the calorific value, sulphur percentage and boiling water duration test on groundnut shell, maize cob and rice husk made into pellets through the process of densification. Rice husk gave 17.35 kJ/kg, maize cob 16.16 kJ/kg and 17.35 kJ/kg for groundnut shell calorific values and 5.23%, 4.25%, 6.0% respectively for sulphur content. For boiling 2 kg of water, it took them 15 minutes, 13 minutes and 10 minutes respectively, while Purvis and Graig (1998) treats a small scale biomass fired turbine power plant.

Therefore the design and construction of a suitable machine that can compress wood waste and agricultural waste materials into briquette which can be used as fuel would therefore be a solution to the problem of environmental resources conservation.

Generally briquette processing machine are relatively large, heavy and costly. What is needed is a small, light, simple and cheap press which can be constructed with local materials available locally. Considering the fact that a manual operated press required the person, who pulls or pushes down the level to exert a great force up to about twice every minute it became clear that gradual exhaustion causes diminishing performance.

There is also a tendency to produce briquettes of irregular size or compaction, depending on compressing system. If filling the mould is done manually, apart from producing irregular sizes and low rate of production per machine it will require a number of machines to achieve an output. Biomass residues normally have much lower ash content (except for rice husk with 20% ash) but their ashes have a higher percentage of alkaline minerals, reasonable especially potash. These constituents have a tendency to devolatalise during combustion and condense on tubes, especially those of super heaters. These constituents also lower the sintering temperature of ash, leading to ash deposition on the boiler's exposed surfaces. The ash content of some types of biomass are given in Table 1.

Table 1: Ash content of some biomasses (Grover and Mishra, 1996).

Biomass	Ash content (%)	Biomass	Ash content (%)
Corn cub	1.2	Coffee husk	4.3
Jute stick	1.2	Cotton shells	4.6
Sawdust(mixed)	1.3	Tannin waste	4.8
Pine needle	1.3	Almond shell	4.8
Soya bean stalk	1.5	Areca nut shell	5.1
Bagasse	1.8	Castor stick	5.4
Coffee spent	1.8	Groundnut shell	6.0
Coconut shell	1.9	Coir pith	6.0
Sunflower stalk	1.9	Bagasse pith	8.0
Jowar straw	3.1	Bean straw	10.2
Olive pits	3.2	Barley straw	10.3
Arhar stalk	3.4	Paddy straw	15.5
Lantana camara	3.5	Tobacco dust	19.1
Subabul leaves	3.6	Jute dust	19.9
Tea waste	3.8	Rice husk	22.4
Tamarind husk	4.2	Deoiled bran	28.2

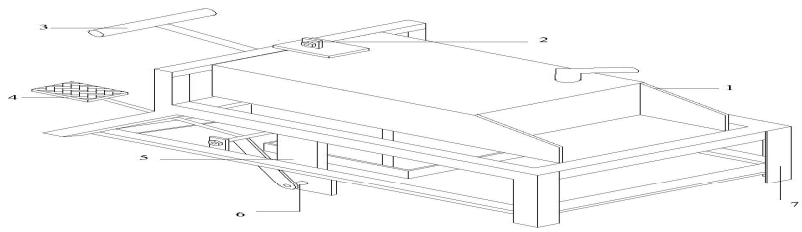
However attractive a residue-conversion technology may seem in terms of its efficiency or cost-effectiveness in producing fuel, it must conform to the local dynamics of agriculture or it will not be adopted.

This paper treats the design of a small pedal operated briquette press to produce three (3) briquettes of about 220 mm x 80 mm x70 mm at a time using agricultural and wood wastes . It also makes manual operation as simple as possible and allows variation in the compression ratio. However, the thermal properties of the briquettes are not to be treated in this work.

Design analysis

When designing the briquette machine press (figure 1), consideration is given to the behaviour of the machine and its structural members, under the action of external loads (Archie *et al.*, 1983).

Based on the above, values of the following were calculated: working stress, ultimate stress, compression ratio, compressive force, effort applied and efficiency (Brandy and Clauser, 1994).



S/no	COMPONENTS	MATERIAL	QTY	DESCRIPTION
1	MOULD BOX	MILD STEEL	1	PLATE
2	COVER LOCK	MILD STEEL	1	FLAT BAR
3	PRESSURE HANDLE	MILD STEEL	1	SQUARE BAR
4	PRESSURE PEDAL	MILD STEEL	1	ROUND BAR
5	PISTON ARRANGEMENT	MILD STEEL	1	FLAT BAR & PLATE
6	SUPPORT SHAFT	MILD STEEL	1	ROUND BAR
7	FRAME	MILD STEEL	1	ANGULAR BAR

Figure 1: Pedal briquette compression machine

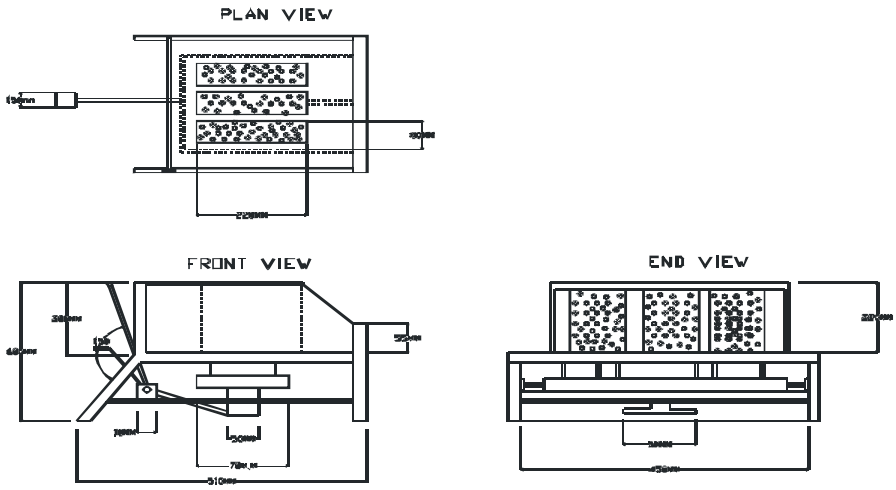


Figure 2: Isometric drawings of briquette compression machine

Machine description and Principle of operation

The briquette compression machine (figure 1) has a similarity both in function and design with popular baler used in agricultural field to compact collected hay into bales to be stored for stock feeding or bedding. The machine converts briquette into compacted bales to be used or stored in form of solid fuels. This machine (figure 2) is constructed using hydraulic based principle of sliders crank mechanism.

Manual briquette press has different components. These include a mould box with a cover, unto which a toggle lever is rolled, a piston briquette unit operated with the lever in a vertical position. The cover plate is slide open the mould which is filled with the mixture of waste material (i.e.: saw-dust) and binder (starch) by means of hand trowel. The cover is closed and the lever is pulled down for compression. The mould is already smeared with engine oil to prevent adhesion, the pre- mixed fibrous waste and adhesive is fed into the mould space (220mm x 80mm) between the mould and compactor. Again in its vertical position the cover is slide aside and the lever is press downward to eject the compressed briquette. Prior to the ejection, the remaining water which was used to ferment the waste material is taken out during compression through holes provided to that effect at the bottom of the moulds. The machine can be operated by one (1) or more persons.

Figure 3: Briquette compression machine with briquette samples

Figure 4: Briquette samples

Performance Evaluation

Machine Performance

To carry out these tests, fibrous waste (saw dust) was obtained from a saw mill. The saw dust was then mixed with industrial starch as a binder; 100% saw-dust as Inegbenebor (2002). The premixed fibrous waste and adhesive of mass (m) is weighted by means of a weighting balance and the fed into the mould through the space between the compactors and the mould until the mould is completely filled up to an initial height (H). The machine (figure 3) is then operated to compress the fibrous waste in the mould. After the compression, briquettes (figure 4) are ejected and the final height (h) is measured and recorded. Also the time taken (t) for the operation is recorded using a Casio Databank stop watch. The performance of the machine is then determined from the obtained data as follows:

True density $(\rho_t) = \frac{M}{V}$ ---------- (1)

Apparent density $(\rho_a) = \frac{M}{V_o}$ ---------- (2)

Percentage increase in density of compressed briquette; η_d

$$\eta_d = \frac{\rho_t - \rho_a}{\rho_a} \times 100\%$$ ---------- (3)

Machine capacity, c

$$c = \frac{N \times 60}{t}, per\ hour$$ ---------- (4)

Where: M = mass of mixed fibrous waste, kg

H= height of mould, m, h = height of compressed briquette, m

T= time taken to complete one operation, minutes, A_o = area of mould, m^2

V_0 = volume of mould, m^3

V = volume of compressed briquette, m^3

ρ_t = true density of briquette, kg/m^3

ρ_a = apparent density of briquette, kg/m^3

N = number of briquettes per operation

RESULTS AND DISCUSSION

The results of the performance tests are presented in the table 2 below:

Table 2: Results of the performance tests.

S/N	Mass of fibrous waste (kg)	H(m)	h(m)	$V_0(m^3)$	$V(m^3)$	ρ_t	ρ_a	η_d
1	1.25	0.09	0.07	4.752	3.696	338.2	263.0	28.6
2	1.28	0.09	0.07	4.572	3.696	346.3	269.4	28.5
3	1.21	0.09	0.07	4.572	3.696	327.4	254.63	28.59
4	1.24	0.09	0.07	4.572	3.696	335.5	260.9	28.58
5	1.27	0.09	0.07	4.572	3.696	343.6	267.26	28.6
Average	1.25 (0.027)*	0.09	0.07	4.752	3.696	338.2 (7.394)*	263.04 (5.779)*	28.58 (0.043)*

* Standard deviations.

The machine was operated successfully and the produced briquettes were removed smoothly without any problem. However, upon drying a noticeable shrinkage was observed on the sizes of the briquettes as 210 mm x 80 mm x 67 mm as a final product. Upon burning, Inegbenebor (2002) found that the solid fuel briquettes burnt with yellow flame with moderate black smoke, indicating incomplete combustion due to poor air-fuel ratio. He could not ascertain the reason for that. However, our results shows that solid briquettes (SB) are indeed unsuitable for cook stoves and give excessive smoke unless broken into small pieces of l-2 cm in thickness as reported by Grover and Mishra (1996). This could be associated to the fact that the binder proportion in the briquette makes it harder with high binder content or brittle when the binder is in low quantity (figure 5). Furthermore, their shape and sizes have a great influence on their combustion characteristics as well as areas of utilization and need to be investigated more deeply.

CONCLUSION

A small light weight fuel briquette machine has been successfully constructed and tested. The machine was able to produce 120 briquettes per hour and it will reduce the cutting down of trees for fuel-wood purposes, thereby preventing deforestation and erosion.

Shrinkages were noticed and the final size of the briquette upon drying was observed to be 210 mm x 80 mm x 67 mm. The average true and apparent densities were also found to be 338.2 kg/m^3 and 263.04 kg/m^3 respectively.

The effect of the binder content on the combustion potentials of the briquette needs to be investigated further.

The product (briquette) obtained from the machine can used as alternate to fuel-wood in domestic cooking and small-scale industries.

The machine will enable agricultural waste to be removed from the environment, thereby preventing environmental pollution.

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