Development and Performance Evaluation of a Manually Operated Hydraulic Briquetting Machine

<Mambo Wilson >[1], <Kamugasha Dick >[2], <Adimo Ochieng>[3], <Okwalinga David Bruno>[4] , <Namagembe Flavia>[5]
[1and2]Jomo Kenyatta University of Agriculture and Technology,
P.O.Box 62000-00200, Nairobi, Kenya.
[2,4 and 5-]Uganda Industrial Research Institute,
P.O.Box 33875, Kampala, Uganda.
Corresponding Author: Mambo Wilson, Email address: mambowilson@gmail.com,

ABSTRACT: Imported briquette machines are expensive, need technical expertise, lack spare parts, and require electricity for operation. The aim of this study is to develop a manually operated hydraulic briquette press, evaluate its performance and assess the physical properties of the briquettes produced. The mould comprised of 100 cylinders having dimensions of 59 mm diameter, and 150 mm height. A hydraulic jack of 50 Tons capacity was selected to exert the compressive force required by the pistons to compact biomass into briquettes. Maize cobs were carbonized as raw material for the purpose of machine testing. Char particles of less than 6 mm and 10% cassava binder ratio was used. Compressed density, production capacity of the machine, machine efficiency, relaxed density, relaxation ratio, moisture content, and chartered index were determined. The average value of production capacity was 122.928 kg/hr, machine efficiency was100%, compressed density was 624.236 kg/m3, relaxed density was 350.093 kg/m3, relaxation ratio was 1.783, moisture content was 13.562% , and shatter index was 98.1464%. The machine therefore attained higher production capacity and all briquettes were free of damage after ejection. The briquettes produced had sufficient density for storage and transportation. The high chartered index of briquettes implies that they were strong enough and durable to withstand handling.

KEYWORDS: Hydraulic briquette press, manual operation, production capacity, relaxation ratio, machine efficiency, strength.

1. INTRODUCTION

Biomass is the most highly consumed primary fuel in Uganda with estimated annual consumption of 44 million tones of trees as fire wood and charcoal. This rate of deforestation signals wood fuel shortage in the near future which demands alternative biomass. Agriculture being the backbone of Uganda results into generation of agro- residues which are nuisance to both public health and the environment when not properly managed (Biomass Energy Strategy, 2013). Utilization of the residues in their loose form as fuel is difficult because of low bulk density, low thermal efficiency and the excessive amount of smoke generated when burnt which leads to indoor air pollution. Densification of the agricultural residues into briquettes is sustainable, economically viable, and environmentally friendly (Grover and Mishra, 1996).

Physical parameters, such as density, moisture content and compressive strength were found to be the best indicators of briquette quality (Kers et. al.,2010). Briquette density and compressive strength are influenced by material composition and the type of briquetting machine used (Križan et al., 2011). Most of the briquette producers in Uganda use manual machines with low production capacity and inconsistent quality, hence their inability to meet the market demand for briquettes. Imported large capacity machines such as screw press, hydraulic press and mechanical piston press are expensive, need technical expertise, lack spare parts, and require electricity for operation (Energy and Environment Partnership, 2013). Given Uganda's electrification rate of 5% (Katimbo et al., 2014) and the high cost of diesel, scaling up locally fabricated machines should ensure that they are manually operated to suite rural conditions. The aim of this study is to develop a manually operated hydraulic briquette press, evaluate its performance and assess the physical properties of the briquettes produced.

2. METHODOLOGY

2.1. HYDRAULIC BRIQUETTE PRESS

The manually operated hydraulic briquette press comprises of a mould, mould cover, press bed, pistons, hydraulic jack, and a pulley system. Design pressure was of 1.5MPa was used, and mild steel material was selected for the machine. The mould has 100 cylinders of 59 mm internal diameter, 150 mm height and 2 mm thickness held in position by two plates with corresponding bores. Mould cover and press bed were designed to withstand shear and bending. The mould cover was made of 2.8mm plate resting on 6mm flat bars aligned to the mould cylinders. The flat bars were welded on hollow sections of 50 mm by 50 mm by 4 mm. Pistons comprised of 20 mm thick discs of 59 mm diameter centrally joined to round bars of 25 mm diameter and 150 mm length which were designed basing on Euler's equation for critical buckling load. The round bars resting on press bed were held in position by fixed cylinders of 30mm diameter and 25 mm height. The press bed selected comprised of 2.8 mm plate welded on 6 mm flat bars welded on hollow sections of 50mm by 50mm by 4 mm. Uniform force distribution was enhanced by a converging base towards a centrally positioned hydraulic jack. Given a design load of 433,759.5N, a hydraulic jack of 50 tons was selected. The mould cover was lifted using a pulley system with mechanical advantage of 4 and velocity ratio of 2.

2.2. EXPERIMENTAL TESTING

2.2.1. Material Preparation

Maize cobs collected from farmers in Tiribogo were carbonized as raw material for the purpose of machine testing. Size reduction of the char was done by pounding and then sieved using a 6 mm sieve. Cassava binder was used because it has high starch content and is readily available. The binder ratio selected was 10% of the char by mass.

2.2.2. Performance Evaluation of the machine

Briquettes were produced by two operators while noting down the total time taken for a complete process cycle (Loading biomass into moulds, compression of biomass, ejection of biomass briquettes, and removal of the briquettes) in seconds for each of the two batches. On ejection of briquettes, mass and dimensions of five randomly selected briquettes were taken using an electronic weighing scale and veneer caliper respectively. Production capacity of the machine in kg/hr was then computed. In addition to that, the number of deformed briquettes in every batch were recorded to compute machine efficiency.

Ejected briquettes on the hydraulic briquette press

2.2.3. Determination of physical properties of briquettes

Compressed density was computed immediately after ejection of briquettes from the weights and dimensions measured. The briquettes were sun dried to a constant weight at an ambient temperature of 27^{o}C for two weeks before determination of relaxed density, relaxation ratio (ratio of compressed density to relaxed density), chartered index as in Obi et. al., 2013, and moisture content by oven drying

3. RESULTS AND DISCUSSION

The table below shows the compressed density, production capacity, machine efficiency, relaxed density, relation ratio, moisture content and shatter index of the briquettes.

Batch Number	Production Capacity (Kg/hr)	Machine Efficiency (%)	Compressed Density (Kg/m^3)	Relaxed Density (Kg/m^3)	Relaxation Ratio	Moisture Content (%)	Chartered Index (%)
1	119.6600	100	622.7388	348.1521	1.7887	13.3750	99.2578
2	126.1960	100	625.7323	352.0334	1.7775	13.7490	97.0350
Average	122.9280	100	624.2355	350.0928	1.7831	13.5620	98.1464

Machine production capacity of 122.93 kg/hr is greater than 43 kg/hr reported by Obi et al., (2013) and 100% machine efficiency shows that the briquettes do not break after ejection by the machine. The compressed density determined (624.24Kg/m^3) is greater than the minimum recommended value (600 Kg/m^3) by Gilbert et al. (2009) and Mani et al. (2006) for safe storage and transportation. Relaxed density (350.09 Kg/m^3) of the briquettes is more than the bulk density of corn cob residue (95.33 Kg/m^3) reported by Oladeji, (2012) which implies that maize cob briquettes require less than a third of the space requirement for corn cob residue. Relaxation ratio (1.7831) is in agreement with the findings reported in O'Dogherty (1989) of 1.65 to 1.80 for hay material. The chartered index (98.15%) exceeds the minimum requirement of 95% for durability (Olorunnisola, 2007) which means that the briquettes produced were durable enough to withstand handling. Briquette moisture content of 13.56% is less 18% requirement for adequate drying (Onchieku et al., 2012), hence attainment of sufficient heating effect (Grover & Mishra, 1996).

4. CONCLUSION

The manually operated briquette machine attained high production capacity of 122.93 kg/hr which makes it suitable for small scale entrepreneurs in rural areas without electricity. All the briquettes were free of damage after ejection, had sufficient density and high chartered index which implies that they were strong enough and durable to withstand handling, storage and transportation.

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