Design of Sawdust Briquette Machine

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Abstract

In this paper, the sawdust briquette machine is designed. Sawmill waste is a big problem especially in urban cities in Nigeria. These wastes are burnt openly which is causing environmental pollution. The wastes can be converted to wealth thereby providing jobs for many unemployed citizens. The principles of machine design were employed to design the essential parts such as hopper, belts, housing barrel, the die, and the shaft. The machine has a production capacity of 95 kg/hr.

Keywords: Briquette, Machine design, Sawdust, Wastes to wealth, Wood wastes

1. Introduction

A briquette is a block of compressed combustible energy carrier suitable for heating. Briquettes are made from waste materials such as old newspaper, sawmill wastes or partially compressed biomass waste. They are largely used as fuel instead of charcoal, firewood or coal. The burning of briquettes depends on the materials used for making them. Briquettes are largely combustible materials made from loose or low density wastes but compressed together into a solid. The compression leads to a product of higher bulk density, uniform size and shape. In Nigeria, the sawmilling industries generate a lot of wastes especially wood sawdust and plank shavings but do not have a proper means of disposing them. These wastes are burnt in the open air causing environmental pollution and contributing to global warming yet wasting energy the can be converted into useful power (Dosunmu and Ajayi, 2002). Increasing demand for alternative energy sources aside from charcoal and petroleum products as well as waste disposal challenges has lead to increased interest in the production of briquettes. Since the raw materials for briquettes are loose and low density, the production of briquettes will be profitable and economical if situated close to sources of raw materials. The compaction of the briquettes should be able to withstand long distance transportation, multiple handling and long time storage. At the beginning of 19^{th} century, sawdust briquettes were made with tar or resins as the binders, but could not gain importance at that time due to relatively higher costs compared to wood and charcoal. But re-emerged in the 1950s when millions of tons of briquettes were produced and consumed. (Lardinios and Klundert, 1993). The interest has since been on the increase. The objective of this paper is to design a screw type sawdust briquette machine that is capable of producing 50mm diameter briquettes from sawdust waste. This is aim at reducing the open air burning of this waste and the attendant environmental pollution. This will create wealth from waste and provide sources of revenue for some people and the government through personal income tax.

2. Materials and Methods

The Hopper: This is where the raw material (saw dust) is feed into the machine. It is made of mild steel, and conical in shape. It is welded to the barrel housing.

The Barrel housing: This is where the raw materials are converted to briquette. It comprises of a cylindrical housing with a tapered die attached to it. It is the housing for the screw extruder. The housing is 560 mm long and 120 mm diameter. A die, 100 mm long and 50 mm diameter is attached to the outlet. The housing barrel volume is 5.9×10^{-3} m^3 while the die volume is 0.34 x 10-3 m^3.

The Screw extruder: The complete screw is fabricated by machining a single mild steel circular rod. The first and the second flights of the screw are hard-faced by welding after machining.

The Die: the die is made of mild steel and machined on the lathe machine to the required dimensions.

The main Stand: The main stand is the support for the barrel housing, the hopper and the shaft. Mild steel square pipes are used. The overall dimensions of the stand are 1000mm long, 500mm wide and 790mm high.

The Belt: The belt is required for power transmission between the motor and the shaft.

The Pulley: The pulley is made of mild steel. There are two of them: one being driven by the electric motor, and the other on shaft driving the screw.

The Bearing: The frictionless bearing supports the shaft on the frame. Two pillow bearings were used.

The Machine Description: The briquette machine is a single extrusion die screw press. It consists mainly of driving motor, screw, die, belts and the housing with a hopper. The belt transmits power from the motor to the screw through the pulley. When the motor is started, raw materials are fed into the machine through the hopper; the raw materials are compressed in the barrel, and extruded through the die. The machine has a production capacity of about 95kg/hr and it is driven by a 3 kW, 1440 rpm electric motor driving the screw shaft at 480 revolutions per minute (rpm). During operation, the rotating screw takes the material from the hopper through the barrel and compresses it against the die which forms a build up of pressure gradient along the screw. The screw continuously forces the materials into the die. Pressure is built up along the screw rather than in a single zone as in the piston type machines.

3. The Design

3.1 The Hopper:

The hopper is designed as a frustum of a square pyramid. Using similar triangles, Fig. 1, below

$$\frac{220+x}{160}=\frac{x}{60} \qquad (1)$$

$x = 132\ mm$

Volume of hopper = volume of the big cone – volume of the small cone.

$= 1/3\ \pi\ (R^2H - r^2h)$

$= 2.235 \times 10^{-3}\ m^3$

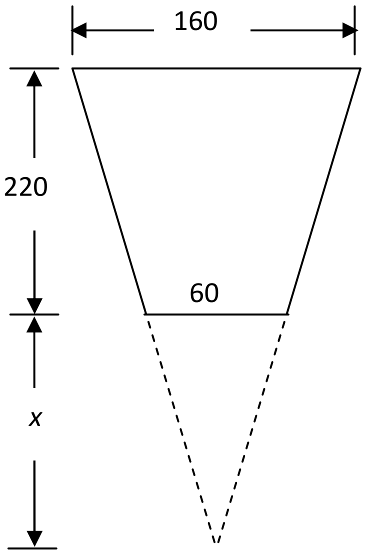

Figure 1: the hopper.

3.2 Housing Barrel:

The weight of the barrel is calculated thus:

Weight = mass x gravitational force

Mass, $m = \rho \times v$ (2)

The material used is mild steel, $\rho_{mild\ steel} = 7861.09\ kg/m^3$

Volume of the barrel = volume of cylinder + volume of the tapered end.

Volume of the cylinder = $\frac{1}{4}\pi d^2 l$ (3)

Where l = length of the cylinder = 530 mm

d = diameter of the cylinder = 120 mm

Therefore, Volume of cylinder = $\frac{\pi \times 120^2 \times 530}{4}$ = $5.994 \times 10^{-3}\ m^3$

The die is a frustum of a cone and is designed, using similar triangles in Fig. 2,

$$\frac{100 + x}{120} = \frac{x}{50} \quad (4)$$

$x = 71.4\ mm$

volume of tapered die = volume of big cone – volume of small cone

$= \frac{1}{3}\pi\left(r_1^2 h_1 - r_2^2 h_2\right)$

= 1/3 x 3.142 x (60^2 x 171.4 – 25^2 x 71.4)

= 5.99 x 10^{-4} m^3

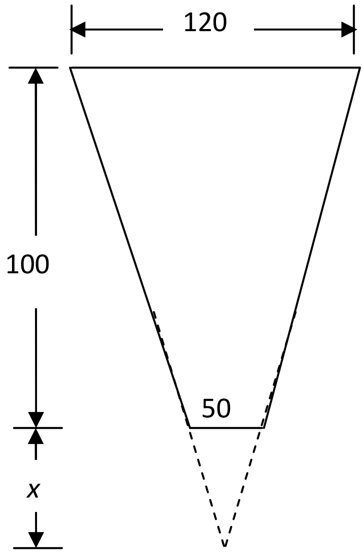

Figure 2: Tapered die

Total volume of the Barrel = volume of the cylinder + volume of the tapered end

= 5.994 x 10^{-3} m^3 + 5.99 x 10^{-4} m^3

= 6.593 x 10^{-3} m^3

Calculating the weight of sawdust

Weight of sawdust, W = mass of sawdust x density of sawdust

Mass of sawdust = volume x density

Bulk density of sawdust (assuming 10% moisture content) = 267 kg/m^3

Volume of sawdust = volume of hopper + volume of barrel

= 2.235 x 10^{-3} m^3 + 6.593 x 10^{-3} m^3

= 8. 828 x 10^{-3} m^3

The mass of sawdust = $V_{sawdust} \times \rho_{sawdust}$ = 8. 828 x 10^{-3} m^3 x 267 kg/m^3

= 2.357 kg

Therefore, weight of sawdust = $m_{sawdust} \times g$ = 2.357 x 9.81 *N*

= 23.123 *N*

3.3 Belt:

Capacity of motor – 3 kW at 1440 rpm

Service life = 8 hours / day

Shaft speed = 480 rpm

Center distance of the pulleys = 750 *mm*

For the screw press, the belt is V-belt with A cross section.

For A cross section, the minimum pitch diameter of the small pulley is 125 *mm*

The diameter of the driven D = $d\left[\frac{speed\ of\ smaller\ pulley}{speed\ of\ bigger\ pulley}\right] = \frac{125 \times 1440}{480}$ (5)

= 375 *mm*

The total length, *L*, of the belt is obtained from an expression according to Bhandari (2010),

$$L = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C} \quad (6)$$

Where *D* = diameter of big pulley (mm) = 375 *mm*

d = diameter of small pulley (mm) = 125 *mm*

C = Centre distance of the pulleys (mm) = 750 *mm*

$$L = 2(750) + \frac{\pi \times (375+125)}{2} + \frac{(375-125)^2}{4(750)}$$

= 2306.23 *mm*

$$\alpha_s = 180 - 2\sin^{-1}\left(\frac{D-d}{2C}\right) \quad (7)$$

Where α_s = wrap angle for small pulley (degrees)

$$\alpha_s = 180 - 2\sin^{-1}\left(\frac{375-125}{2\times 750}\right)$$

α_s = 160.81^0 = 2.81 *radians*

The velocity of the belt is

$$v = \frac{\pi \; d \; n}{60 \times 1000} = \frac{3.142 \times 125 \times 1440}{60 \times 1000} = 9.426 \text{ m/s} \quad (8)$$

$$\text{Number of belts required} = \frac{P \times F_a}{P_r \times F_c \times F_d} \quad (9)$$

Where P = drive power to be transmitted = 3kw

F_a = correction factor = 1.2

P_r = power rating of single V – belt = 1.0

F_c = correction factor for belt length = 0.95

F_d = correction factor for arc of contact = 1.06

$$\text{Number of belts required} = \frac{3 \times 1.2}{2.24 \times 1.0 \times 1.08} = 1.488$$

= 2 belts

3.4 Shaft:

The shaft is made of mild steel and the pulley is keyed into it.

The yield strength of the material in tension, S_{yt} = 770 N/mm^2 and ultimate tensile strength = 580 N/mm^2

Assuming the load is gradually applied, the combined shock and fatigue factor applied to bending moment, K_b = 1.5 and combined shock and fatigue factor applied to torsional moment, K_t = 1.0

The permissible shear stress, τ, is taken to be 30% of the yield strength or 18% of the ultimate tensile strength of the material or whichever is minimum.

Therefore, $\tau = 0.3\, S_{yt} = 0.3\,(580) = 174$ N/mm^2

$\tau = 0.18\, S_{ut} = 0.18\,(770) = 138.6$ N/mm^2

and the lower is *138.6 N/mm^2*

since the pulley is keyed to the shaft, $\tau = 0.75 \times 138.6 = 103.95$ N/mm^2

Let d = diameter of shaft,

M_t = torque transmitted by the shaft,

P = power transmitted by the shaft (W),

N = rpm of the shaft,

τ = permissible shearing stress, and

M_b = bending moment.

The power transmitted by shaft and the torque in the shaft are related according to Machine elements (2013) as

$$P = M_t \omega \tag{10}$$

$$\omega = \frac{2\pi N}{60} \tag{11}$$

$$P = \frac{M_t \times 2\pi N}{60} \tag{12}$$

$$M_t = \frac{30P}{\pi N} \tag{13}$$

The shear stress and transmitted torque are related as

$$\tau = \frac{16 M_t \times 10^3}{\pi\ d^3} \tag{14}$$

$$M_t = \frac{\pi\ \tau\ d^3}{16} \times 10^{-3}\ \text{N/mm}^2 \tag{15}$$

Equating the two equations together, and collecting like terms,

$$d = 36.5 \times \left(\frac{P}{\tau\ N} \right)^{0.33} mm \tag{16}$$

$$d = 36.5 \times \left(\frac{3000}{103.95 \times 480} \right)^{0.33} = 14.44 \text{ mm,} \tag{17}$$

Also, the diameter of the shaft can be calculated as follows

$$\tau = \frac{16\sqrt{\left[(K_b M_b)^2 + (K_t M_t)^2 \right]}}{\pi\ d^3} \tag{18}$$

$$d^3 = \frac{16\sqrt{\left[(K_b M_b)^2 + (K_t M_t)^2 \right]}}{\tau\ \pi} \tag{19}$$

M_t , the torque transmitted by the shaft is given by

$$M_t = \frac{30P}{\pi N} = \frac{30 \times 3000}{3.142 \times 480} \tag{20}$$

$= 59.675\ Nm = 59675\ N\,mm$

$M_b = 127,306\ N\,mm$

$$d^3 = \frac{16\sqrt{(1.5\times127306)^2 + (1.0\times59675)^2}}{103.95\times3.142} \quad (21)$$

$d = 21.34\ mm$, use $25mm$

4. Conclusion

The briquette machine has been designed. This machine has the capacity to produce 95kg of briquette in one hour. It can be easily fabricated with materials sourced locally. This project will provide job opportunity to the unemployed graduates, and small-scale entrepreneurs can be empowered by the government by making briquette from sawmill wastes. This will reduce unemployment rate in Nigeria and dependence on petroleum products for heating and cooking and also utilize waste generated by the sawmill industries thereby reducing open air burning and attendant environmental pollution.

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