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Redesign of Saw Dust Briquetting Machine in Plywood Industry

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Abstract: A briquette is a block of compressed coal, biomass or charcoal dust that is used as fuel to start and maintain fire. Briquetting is a mechanical compaction process for increasing the density of bulky materials. This process is used for forming fine particles into a designed shape. It can be regarded as a waste control measure in the case of production of briquettes from agricultural wastes. However, depending on the material of interest, briquetting can be used to provide fuel source as a preventive measure to many ecological problems. Briquetting is a high-pressure process which can be done at elevated temperature or at ambient temperature depending on the technology one wants to employ. Various briquetting machines have been designed, ranging from very simple types which are manually operated to more complex ones mechanically or electrically powered. Generally, briquetting operations have developed in two directions, mechanically compression (hydraulic or pistons) and worm screw pressing types. Currently available in Western India Plywood, produced sawdust briquettes have suboptimal densities, causing incomplete burn and excess smoke. Here I made Attempts to improve this technology, particularly by adjusting the screw length to diameter ratio, the screw rotation speed, feed pressure, and residence time in the extension chamber as a means of producing a higher-density, better quality briquette.

Keywords: Briquette, Sawdust, Plywood, Redesign.

I. INTRODUCTION

A briquette is a block of compressed coal, biomass or charcoal dust that is used as fuel to start and maintain fire. Briquetting is a mechanical compaction process for increasing the density of bulky materials. This process is used for forming fine particles into a designed shape. It can be regarded as a waste control measure in the case of production of briquettes from agricultural wastes. However, depending on the material of interest, briquetting can be used to provide fuel source as a preventive measure to many ecological problems. Briquetting is a high-pressure process which can be done at elevated temperature or at ambient temperature depending on the technology one wants to employ.

During this process, fine material is compacted into regular shape and size which does not separate during transportation, storage or combustion. In some briquetting techniques, the materials are simply compressed without addition of adhesive (binderless briquettes) while in some, adhesive material is added to assist in holding the particles of the material together. Generally, briquetting process has focused more on the production of smokeless solid fuels from coal and agricultural wastes. There are various techniques which have been used to produce smokeless solid fuel from coal fine. The most common technique is the use of roller press using only moderate pressure and binder. Note that the machines employed for this process are also used to make other kind of non-fuel briquettes from inorganic materials such as metal ores. However, briquetting of organic materials (agricultural wastes) requires significantly higher pressure as additional force is needed to overcome the natural springiness of these materials. Essentially, this involves the destruction of the cell walls through some combination of pressure and heat. High pressure involved in this process suggests that organic briquetting is costlier than coal briquettes.

Various briquetting machines have been designed, ranging from very simple types which are manually operated to more complex ones mechanically or electrically powered. Generally,briquetting operations have developed in two directions, mechanically compression (hydraulic or pistons) and worm screw pressing types. Sawdust is waste material from all types of primary and secondary wood processing between 10 and 13% of a log is reduced to sawdust in milling operations. Sawdust is bulky, and is therefore expensive to store and transport. Also, the calorific value of Sawdust is quite low, so that briquetting is an ideal way to reduce the bulk, to increase the density, and thus to increase the calorific value. The equipment required for producing sawdust briquettes consist of a drier, a press and an extruder with a tapered Screw and a large revolving disk.

The sawdust briquettes are formed under sufficiently high pressure to produce cohesion between wood particles. The lignin softens and binds the briquette, so no additional binder is required. The advantages of producing sawdust fuel briquettes include:

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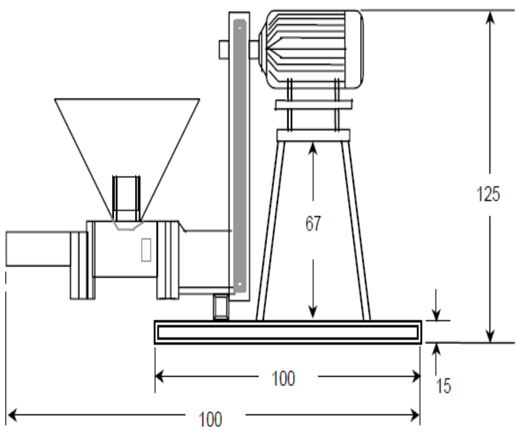
- The price of sawdust fuel briquettes is about the same as fuel wood but is much More convenient to use as they do not require further cutting and chopping.
- They burn very well in any kind of solid fuel stove and boiler
- They ignite quickly and burn cleanly, producing only 1% to 6 % ash
- The briquettes don't contain Sulphur and burn without producing odor
- The burning of 1 kg of sawdust fuel briquettes produces 18000 KJ caloric power, roughly equivalent that of medium quality coal.
- A briquette plant may be profitably integrated into larger sawmilling operations.

II. REDESIGN OF BRIQUETTE MACHINE

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 x 10-3 m3 while the die volume is 0.34 x 10-3 m3.
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 buildup 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.



All dimensions are in cm

The Design

1. The Hopper:

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

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

x = 132 mm

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

= 1/3 π ($R^2H - r^2h$) = 2.235 x 10^{-3}

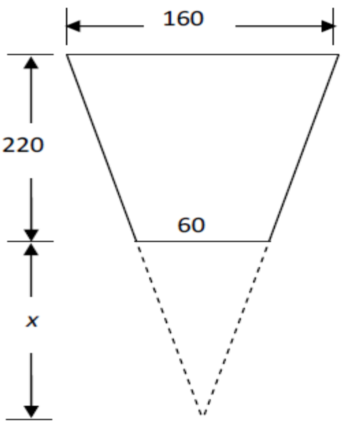

Figure 1: the hopper.

Housing Barrel:

The weight of the barrel is calculated thus:

Weight = mass x gravitational force

Mass, m = ρ x v (2)

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

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

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

Where l = length of the cylinder = 530 mm

d = diameter of the cylinder = 120 mm

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

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

$$\frac{100+x}{120} = \frac{x}{50}$$

x = 71.4 mm

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

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

= 1/3 x 3.142 x (602 x 171.4 – 252 x 71.4)

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

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 =$V_{sawdust}$ □□□$_{sawdust}$□

= 8. 828 x 10^{-3} m^3 x 267 kg/m^3

= 2.357 kg

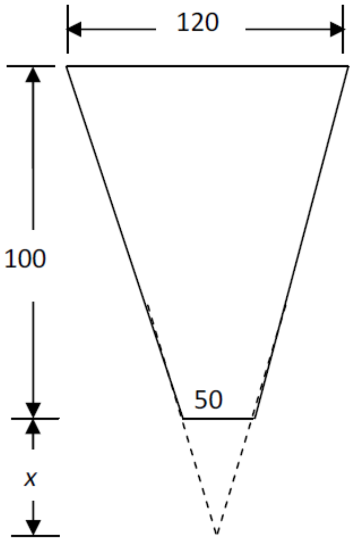

Figure 2: Tapered die

Therefore, weight of sawdust = $m_{sawdust}$ □□g
□= 2.357 x 9.81 N
= 23.123 N

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 = $d\left[\frac{speed\ \ of\ \ smaller\ \ pulley}{speed\ \ of\ \ bigger\ \ pulley}\right] = \frac{125\ X\ 1440}{480}$
= 375mm
The total length, L, of the belt is obtained from an expression according to Bhandari

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

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

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

= 306.23 mm
$□_s$ =180 2sin^{-1}$\{\frac{D-d}{2C}\}$
Where,
$□_s$ = wrap angle for small pulley (degrees)
$□_s = 180 - 2sin^{-1}(\frac{375-125}{2*750})$
$□_s$ = 160.81^0 = 2.81 radians
The velocity of the belt is,
V= $\frac{\pi dn}{1000*60} = \frac{3.142*125*1440}{60*1000}$ =9.426 m/s
Number of belts required = $\frac{P*F_a}{P_r*F_c*F_d}$
Where P = drive power to be transmitted = 3kw
F_a = correction factor = 1.2
P_r = power rating of single V – belt = 1.0

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F_c = correction factor for belt length = 0.95
F_d = correction factor for arc of contact = 1.06

Number of belts required = $\frac{3*1.2}{2.24*1*1.08}$ = 1.488 = 2 belts

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,
$P = M_t\ \omega$
□□□□$\frac{2\pi N}{60}$
$P = (M_t * 2\pi N)/60$
$M_t = \frac{30P}{\pi N}$
The shear stress and transmitted torque are related as,
□□□□$\frac{16M_t * 10^3}{\pi d^3}$
□$_t = \frac{\pi\tau d^3}{16}$ □□□□□□
Equating the two equations together, and collecting like terms,
d = 3.65 □□$\{\frac{P}{\tau N}\}^{0.33}$□mm
d = 3.65 □□$\left\{\frac{3000}{103.95*480}\right\}^{0.33}$ □□14.44 mm

Also, the diameter of the shaft can be calculated as follows,
$\tau = 16\sqrt{\{(K_b M_b)^2 + (K_t M_t)^2\}}/\pi d^3$
$d^3 = 16\sqrt{\{(K_b M_b)^2 + (K_t M_t)^2\}}/\tau\pi$
M_t the torque transmitted by the shaft is given by,
$M_t = \frac{30P}{\pi N} = \frac{30*3000}{3.142*480}$ = 59.675 Nm = 59675 N mm
M_b = 127, 306 N mm
$d^3 = 16\sqrt{\{(1.5 * 127306)^2 + 1.0 * 59675)^2\}}/(103.95 * 3.142)$
d^3 = 21.34 mm, use 25mm

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.

III. DIE DESIGN AND OPTIMIZATION

Initial die design:
Entry diameter = 38 mm, Exit diameter = 25 mm
Taper angle = 3.73°, Compression ratio =1:7.6

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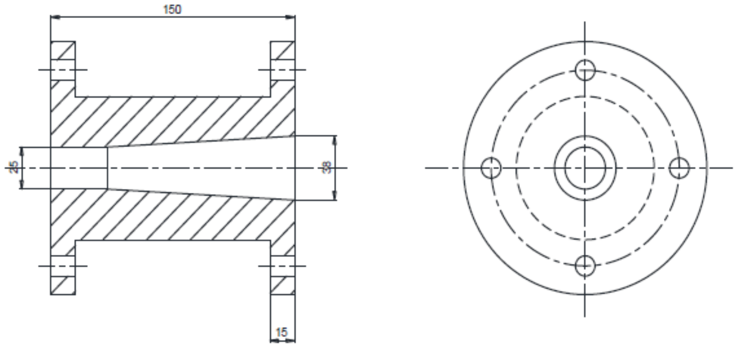

Inference: It is found that the inlet diameter of the die (Ø 38 mm) is less than the exit diameter (Ø 50 mm) of the barrel. Because of the sudden contraction in area, partially densified material got struck within the die entry area.

Modification I:
Entry diameter = 50 mm, Exit diameter = 25 mm,
Taper angle = 6.2˚, Compression ratio = 1:4
Compaction ratio = $\frac{maximum\ \ density}{initial\ \ density} = \frac{1302}{300} = 4.34$

Inference: The problem found in the previous stage has been eliminated in this stage by increasing the inlet diameter of the die (Ø 50 mm). But due to the taper angle is too more, high densification of saw dust place that leads to clogging of material inside the die.

Modification II:
Entry diameter = 50 mm, Exit diameter = 30 mm
Taper angle = 5.19˚, Compression ratio = 1: 6.25
Compaction ratio = $\frac{maximum\ \ density}{initial\ \ density} = \frac{1104}{300} = 3.68$

Inference: In previous stage the taper is too high. Higher the taper increases the strength and durability of the briquette and also the friction between the die surface and the briquette material. In this stage the friction is more so that the output not delivered by the machine. The densified material blocked inside the die as like as the previous design.

Modification III:
Entry diameter = 50 mm , Exit diameter = 30 mm
Taper angle = 5.71˚, Compression ratio = 1: 5.25
Compaction ratio = $\frac{maximum\ \ density}{initial\ \ density} = \frac{1190}{300} = 3.966$

Inference: Increasing the die-thickness (i.e., die length) or decreasing die diameter would increase the amount of shear applied to the feed, which may positively affect the briquette strength and durability. However, too much shear (i.e., excessively long die or very small die-diameter) would block the briquette formation. So the new die with reduced length from 150 mm to 120 mm has been machined and trials were conducted. Still the compaction ratio is high material output was not able to delivered by the machine.

Modification IV:
Entry diameter = 50 mm, Exit diameter = 30 mm
Taper angle = 4.28˚, Compression ratio = 1: 6.66
Compaction ratio = $\frac{maximum\ \ density}{initial\ \ density} = \frac{1051}{300} = 3.50$

Inference: In this stage the taper has reduced from 5.71˚ to 4.28˚ and at the entry the sudden contraction in area was modified to continued flow for 15 mm. In this 15 mm length, the same densified material from barrel outlet travelled to the contraction zone. And thus the results were found that quiet discontinuous and rough. So that the further modification requires to achieve the smooth and continuous output.

Modification V:
Entry diameter = 50 mm, Exit diameter = 30 mm
Taper angle = 2.1˚, Compression ratio = 1: 14

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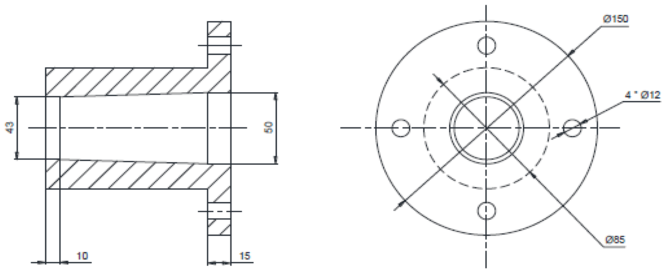
Compaction ratio = $\frac{maximum\ \ density}{initial\ \ density} = \frac{915}{300} = 3.5$



Inference: In previous stage the briquette has bind with inner surface of the die. And the discontinuous and rough briquette output from the machine takes place due to the pressure development overcome the wall friction. So that the taper angle and compression ratio were reduced further to 50% for both to the betterment of briquette formation with the good compressive strength and burning characteristics.

IV. CONCLUSION

In the screw-presses, material is fed continuously into a screw which forces the material into a cylindrical die; this die is often heated to raise the temperature to the point where lignin flow occurred. Pressure builds up smoothly along the screw rather than discontinuously under the impact of a piston. If the die is not heated then temperatures may not rise sufficiently to cause lignin flow and a binding material may have to be added. This can be molasses, starch or some other cheap organic material. It is also possible to briquette carbonized material in a screw-press and in this, as lignin have been destroyed, a binder has to be employed. Some low-pressure piston machines may also require the use of binders though this is unusual. If the die is heated then the temperature is normally raised to 250-300 °C, which produces a good quality briquette from virtually all organic feeds provided the initial moisture is below about 15%. The briquettes from screw machines are often of higher quality than from piston units being harder and less likely to break along natural fracture lines. Screw presses are usually sized in the range 75-250 kg/in though larger machines are available. The capital costs of screw machines may be a little less than piston units though because of size differences it is difficult to make direct comparisons. However, their maintenance costs are usually much higher because of the considerable wear on the screws which have to be re-built rather frequently. They also have a higher specific energy demand than piston machines. However, maintenance costs of screw presses are usually much higher because of the considerable wear on the screws which have to be re-built rather frequently.

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