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# Design and Manufacturing of Screw Briquetting Machine for Compaction of Biomass

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**Abstract -** *Earth's energy demands are growing since the dawn of industrialization. Major part of which comes from burning of fossil fuels. Renewable energy sources are sought to cope up with energy demands and control harmful emissions. Efforts are made to increase the dependency on renewable energy sources, worldwide. Farming employees 55% of population in India and this field still needs a lot of research and development. Agricultural waste is produced and wasted on a large scale in India. This waste has energy potential which, in turn is wasted. Agricultural waste can be used to manufacture high calorific value biomass briquettes, giving rise to entrepreneur opportunities and energy substitutes. We focus on developing a low investment machine providing extra income opportunities `to farmers. We further study different compositions of briquettes to increase calorific values. This project will provide better opportunities to farmers and environment friendly energy solution. Further advancements can be made to increase the efficiency and obtain a high calorific value by trying various raw materials.*

***Key Words***: Biomass briquettes, Calorific Value, Screw extrusion technology, Renewable energy, Agricultural waste.

## 1. INTRODUCTION

The demand of energy is increasing day by day and supply sources are limited. It is globally red for fossil fuel link Petrol, Kerosene, Natural Gas, LPG, Lignite and other coal. It is necessary for us to find an option for these fuels. Fossil fuels are the major energy source that are being used in the world today.

Fossil fuels as the name suggests are derivatives of plant and animal fossils that are millions of years old. These are primarily formed from the remains of the decayed plants and animals of the carboniferous era. Industrial revolution has shown the way and it's still going on. But their over-consumption can lead to serious environmental issues such as air pollution. Fossil fuels release carbon dioxide, nitrogen dioxide, Sulphur dioxide, carbon monoxide etc. when burnt that can have severe consequences on the habitats. They are non-renewable sources of energy as they are derived from pre-historic fossils and won't be available once they are fully used. Their sources are limited and they are depleting at a faster rate.

### 1.1 Problem Statement

To design and develop the screw briquetting machine for compaction of biomass obtained from agricultural waste of diameter 30-70 mm and to improve its Calorific Value by testing of various compositions of briquettes.

### 1.2 Literature Review

Joseph Ifeolu Orisaleye, Sunday Joshua Ojolo, Joseph S. Ajiboye, Mathematical modelling of die pressure of a screw briquetting machine, 2019/4/9

In this paper, mathematical models were developed to study the die pressure using a plug flow theory. Effects of die entry angle, die reduction ratio, length of briquetting die, biomass compact yield strength and friction on the die pressure were investigated using the models. Increasing the die entry angle, reduction ratio, compact yield strength and friction coefficient resulted in increase in the die pressure.

- Kamalakanta Sahooa,, Edward Bileka,,Richard Bergmana,, Sudhagar Mani Techno-economic analysis of producing solid biofuels and biochar from forest residues using portable systems 2019

In this study, the techno-economic assessment of three portable systems to produce woodchips briquettes (WCB), torrefied woodchips briquettes (TWCB) and biochar from forest residues were evaluated using pilot-scale experimental data. A discounted cash flow rate of return method was used to estimate minimum selling prices (MSPs) for each product, to conduct sensitivity analyses, and to identify potential cost-reduction strategies.

- Juan Arevalo Grimaldo quispe, Carlos reymundo Sustainable energy model for the production of biomass briquettes based on rise husk in low income agricultural areas. 2017

The design of the machine is based on the results of a comprehensive study of the complicated process of biomass compaction. The patented structure meets two main goals:

The elimination of axial forces, leading to increased lifetime of the bearings, and the new modular design of a pressing chamber and tools with their geometry based on the application of a mathematical model.

- M.FadzliHamid,, M.YusofIdroas,,M.ZulfikarIshak An Experimental Study of Briquetting Process of Torrified Rubber Seed Kernel and Palm Oil Shell 2017

There was a significant effect of optimizing the composition of starch as binder and water to the physical characteristics of the biomass briquettes. In fact, the stronger and more stable particles of the biomass briquettes that improved their hardness and durability was realized by adding the starch as the binder, which controlled its composition together with the composition of water in the mixture prior to the briquetting process.

- Daniel S Madariya, Production of loose biomass briquettes from agricultural and forestry residues, International Conference on Food, Agriculture, and Natural Resources, FANRes2017 Sustainable agriculture production is a key on achieving food consumption adequacy in developing country but many farmers should struggle more in fulfilling production sustainability whilst keeping on with the economical target. The research was endeavored to seek a viable application on achieving agricultural sustainability and recognizing farmers and community biggestobstacles such as energy by turning agricultural waste such as corn cob and rice husk into bio briquettes.

## 2. Material Selection for Briquettes

Biomass briquettes are a type of fuel that is substitute to coal and the charcoal. The biomass briquettes are generally made up of the trees waste, agriculture waste and forest waste. Biomass briquettes are also made up of green waste are converted into the high density biomass or increased the calorific value of the biomass briquettes with the help of the machines that are uses the binder or binder less technique or some organic materials. In biomass briquetting machine there is no use of any chemical or other natural materials for nature, it is 100% natural. The major raw materials for manufacturing biomass briquettes are sawdust, forestry leaves, dry tree leaves, wood waste, another kind of organic waste, risk husk, cumin waste, cotton flowers, cotton stalk, madden bhells, bettelnut shells, almond shells, pista covers, castor seed shells, jute waste, bamboo dust, groundnut shells, coffee husk, bagasse etc. this sawdust are offers eco- friendly production of white coal briquettes for biomass briquettes. Biomass are generally used for type of thermal applications like boilers, for heating purpose, heating in cold weathers and hotels, canteens, kitchen appliances. This sawdust are compressed part is to make the briquettes.

Starch is the common binder it is usually costly than other. In general, nearly about 3-7 of starch is needed to make the briquettes. Starch sources are cornstarch, wheat starch, maize flour, wheat flour, rice flour, cassava flour, combine the starch, which is added to water and heated to form a sticky consistency, then adding to the mixer to be mixed with the charcoal powder. Clay is available at almost free cost in many places. A briquette contain nearly 14 of clay. Clay does not add the heating value of the briquette. If more clay is added, the briquette will ignite and burn halfly. Besides, clay will turn into ash after burning, which blocks the passage of heat, resulting in the loss of heating value of the charcoal. Gum Arabic, also known as acacia gum, this gum is a natural gum collected from acacia tree, which is very common in Africa Sahel, especially Senegal, Sudan, etc. Gum Arabic is used as binder material for coal briquette. No smoke emitting, or no thermal treatment is needed. Wood tar process is generally arise during carbonization process and recovered from stationary retorts. Pitch is liquid that remains after the distillation of coal tar. Tar is have liquid where pitch is solid.

## 3. Working Principle

We are going to manufacture a machine which replaces the use of fossils fuels such as kerosine, coal, pollution making material. In this we are using agricultural waste product to manufacture briquettes. In a biomass briquette machine first we have to start a machine. When we started the machine the motor starts running. We have connected the motor shaft with the screw via coupling. This power transmission used for screw propeller which impact force on material. At the end of screw propeller we have mounted die and hooper on it. When machine gets started we have to put mixture of raw material and binding material in it. It contains raw materials such as sawdust, agriculture waste, rice husk, coffee husk, coir pitch, sugarcane, bamboo dust, wheat straw etc and binding material such as starch, clay, gum Arabic, wood tar, paper pulp etc.

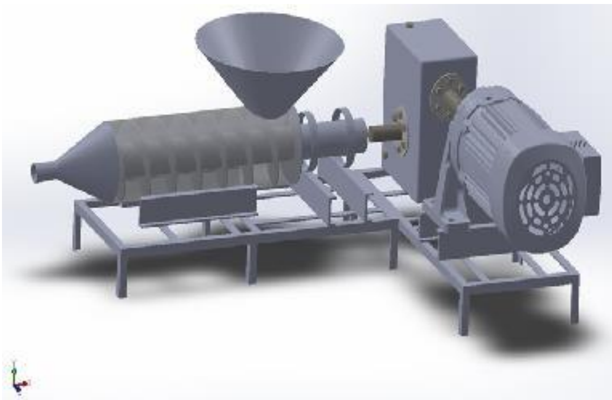

Fig_1: Cad Model of Biomass Briquetting Machine

## 4. Design Calculations

Here, The maximum load due to all factors = 100 kg
F= 100kg = 100 x 9.81 = 981 N.
We know that he load on each link,
F1 = 981/4 = 245.25N.
Assuming a factor of safety as 2, the links must be designed for a buckling load of
Wcr = 245.25 x 2 = 490.5 N
Let t1= Thickness of the link
b1= width of the link
So, cross sectional area of the link = A = t1x b1
Assuming the width of the link is three times the thickness of the link, i.e.b1= 3 x t1
Therefore
A= t1x 3 t1 = 3 t12
And moment of inertia of the cross section of the link,
I = 1/12 t1b13
= 2.25 t14
We know that I = AK2, where k = radius of gyration.
K2 = I/A = 2.25 t14 / 3 t12 = 0.75 t12
Since for the buckling of the link in the vertical plane, the ends are considered as hinged, therefore, the equivalent length of the link
L = l = 500 mm.
And Rankin's constant, a = 1/ 7500

Now using the relation,

Wcr = 1 + a ( L / K)2
Here f = 100 N / mm2
490.5= 100 x 3 x t12
490.5 = 1 + (1 / 7500) (5002/0.75t12) 300 t12
490.5=1 + 44.44 / t12 300 t14 – 490.5 t12 –44.44x 490.5 = 0
t12 = 34.567
t1 = 5.87 mm
b1 = 3 x t1 = 3 x 5.87 = 17.638 mm.
But the standard angle available of **35x 35x 5** hence for safer side we have selected it. This can bear the impact loading. Hence our design is safe.

**Specifications of worm gear box:**

Gear Ratio: 50:1
Driver:
Diameter (d): 18 mm
Key: Width- 7 mm
Height- 3 mm
Driven:
Diameter (D): 32 mm
Key: Width- 20 mm
Height- 4 mm

Motor Specifications:

1.5 HP, 1500 RPM (220V)

**The motor selected for the application is single phase brake motor**

**Design of Shaft:**
We know, $T = G\theta = \tau$
(notations have usual meaning) $J\ L\ R$
Material: Mild Steel
$\tau = 16\sqrt{(K\ M\ )2 + (K\ M\ )2}$
where, $c = d1\ max\ \pi d3(1{-}c4)\ b\ b\ t\ t\ do$

**Design of shaft:**

Material: Mild Steel
$Syt = 480\ MP\ \tau max = 0.30Syt$
$Sut = 720\ MP\ \tau max = 0.18Sut$ (whichever is minimum)
- By V.B. Bhandari

Now,
$\tau max = 0.3 * 480 = 144\ N/mm2$
$\tau max = 0.18 * 720 = 129.6\ N/mm2$
Thus, $\tau max = 129.6\ N/mm2$ is selected.
$\therefore Mt = 7853.95 * 103\ N.mm$

Considering shaft to be uniformly loaded,

$Mb$ (max) at bearing = $Wl\ 2$
(Source: V.B.Bhandari)

$106.48 * 3502 = = 652.19 * 106\ N.mm2\ 2$
Now, $\tau = 16\sqrt{(K\ M\ )2 + (K\ M\ )2}\ max\ \pi(1{-}c4)d2\ b\ b\ t\ t$
$\therefore 129.6 = (1 - c\ 4\ 2$
$\sqrt{(KbMb)2 + (KtMt)2}$
$do = 33.43\ mm\ or\ 35\ mm\ (approx)$

From Screw Conveyor Corporate Catalogue and Engineering Manual, we select screw of 4 inches outer diameter.
By referring to research papers, $\boldsymbol{pitch = diameter}$

Thus, $pitch\ = diameter\ of\ shaft = 35\ mm$

Now, Standard helix angle is given by,
Bearing selection:
$\alpha = \tan{-1}\ n.p\ \pi d$
$\therefore \alpha = \tan{-1}$
1. (0.035) = 17.65° (0.035)

Equation of dynamic load, $P = XFr + YFa$
When bending is subjected to pure radial load, $P = Fr$
And to pure thrust load, $P = Fa$ (By V.B.Bhandari)

As load acting on bearing is its self weight and weight of biomass weight.
Assuming overall weight of 200 N,

By V. B. Bhandari,
Radial life of bearing,

$P = 200\ N$

For ball bearing, $p = 3$
$C\ p\ L10 = (a)\ P$

For agricultural machines, $L10h = 300\ to\ 3000\ hrs, N = 300$
$rpm$
Assuming, $L10h = 1500\ hrs$, we calculate Rated life in hours.

$L10 = (a)\ P$
$C\ 3\ 2.7 = (a)\ 200$
Thus, dynamic load capacity, C= 280N
$\therefore C = 280\ N$
Hence from bearing catalogue, we select following dimensions.
Inner diameter- 35 mm
Outer diameter- 60 mm

Hence, we select 60*35 bearing.
From Screw Conveyor cooperation catalogue and engineering manual,
Horsepower requirement (HP) to drive the screw conveyor is taken as:

Where, Q= capacity (kg/min) = 40 kg/min
L= (Length) = 350 mm
K= constant for biomass= 1.25
$P = Q.\ L.\ K = 24\ kW$

Substituting all this in above equation, we get,

$P = 0.7291\ kW$

$HP\ requirement = P * 1.36$

$\therefore HP\ requirement = P * 1.36 = 0.7291 * 1.36 = 0.9916\ HP$

Therefore, we select motor of 1.5 HP single phase motor of 1500 RPM.

**Hopper Design**

(Truncated cone)
Assume, h = 0.5 m
r = 0.1m
$V = 1\ \pi h\ (R2 + r2 + rR)\ 3$
$\rho$ = 200 to 300 kg/m3 (average range of biomass density)
For m = 25 kg, (assumption)
$\rho = m\ 25$
$= 0.0833\ m3$
Now,
$\rho\ 300$
Thus, r = 0.1 m
And R = 0.3405 m
And h= 0.1 m
$V = 1$
$\pi h\ (R2 + r2 + rR)\ 3$
$\therefore 0.0833 =$
1
$(0.5)(R2 + 0.12 + (0.1)R)\ 3$
$\therefore R = 0.3405\ m$
Thus, hopper design is done!

No. of plates = 6
Pitch = diameter = 35 mm
Diameter of plate = 100 mm
Thickness = 2 mm
Now, density is given as,
$\therefore V = \pi * 2 * (1002 - 352) * 6\ 4$
$\therefore V = 82702.426\ mm3$
$m\ \rho = V$
$\therefore m = 6.5\ kg$
$\therefore w2 = 6.5 * 9.8 = 96.68\ N$
Therefor total weight of shaft = w1 + w2 = 106.48 N

## 5. RESULT

Different briquettes sample had been tested using calorimeter optimum result obtained while testing is:

Combination of dry leaves, paper pulp, bagasse, cow dung.

| | |
|---|---|
| Mass of water | 2.33 Kg |
| Specific heat of water | 4180 J/KgK |
| Initial temp. of water | 29 °C |
| Mass of fuel | 0.002 Kg |
| Final temp. of water | 32 °C |
| Calorific value of fuel | 3495 Kcal/Kg |

From the above result we can confirm that if we add the materials with higher calorific value, the calorific value increases overall.

## 6. CONCLUSIONS

A large volume of agricultural by products being generated in India and which constitute environmental hazards. Call for effective utilisation of that high grade biomass material for solid fuel called briquette. Hence it can be concluded that the waste material like dry leaves, wheat straw, saw dust, etc. are feed stocks for the biomass briquette. Generally dry leaves and wheat straw are burnt to reduce waste, which causes several pollutions to environment, but if wisely handled these wastes can then could be a better option for briquetting. Hence for an agricultural country like India that produces huge amount of agricultural waste every year, use of these waste as a briquette can be economically viable, sustainable and environment friendly solution. And also as machine concerned, it can be concluded that by using simple mechanism with widely available machine element the machine cost could be lowered and makes fabrication economical and portable.

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