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Low Pressure Biomass Briquetting from Water Hyacinth

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ABSTRACT: The decreasing availability of fuel wood, coupled with ever rising prices of kerosene and cooking gas in India, has necessitated a consideration of alternative sources of energy for domestic and cottage level industrial use in the country. Energy from biomass is one such alternative. Biomass is a renewable energy source and can be processed into a convenient solid form using briquetting technology. One of the plants that could be used for solid fuel biomass is Water Hyacinth (WH). One of the methods for processing water hyacinth into low pressure biomass briquette is screw type briquetting machine. As so many methods may available for briquetting of biomass, screw type is the one which gives continuous output dislike other techniques. So that optimization of die design is very much essential for efficient operation of briquetting. For the reason the design of die has been optimized for maximizing throughput and also the contribution of moisture content to the strength of the briquette were studied. The compression ratio for this low pressure screw type briquetting machine is determined by conducting trials with different die shape and size.

KEYWORDS: Water hyacinth, biomass, briquette, screw type, low pressure.

I. INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is considered one of the world's worst weeds, invading lakes, ponds, canals, and rivers. It was introduced into many countries during the late 19^{th} and early 20^{th} centuries, where it spread and degraded aquatic ecosystems. It is still rapidly spreading throughout Africa, where new infestations are creating life-threatening situations as well as environmental and cultural upheaval. Because of its extremely high rate of development, Eichhornia crassipes is an excellent source of biomass. One hectare of standing crop thus produce more than 70,000 m³ of biogas. Water hyacinths can be cultivated for waste water treatment. Water hyacinth is reported for its efficiency to remove about 60–80 % nitrogen and about 69% of potassium from water. The roots of water hyacinth were found to remove particulate matter and nitrogen in a natural shallow eutrophicated wetland. Water hyacinth is a free-floating perennial aquatic plant native to tropical and sub-tropical South America. With broad, thick, glossy, ovate leaves, water hyacinth may rise above the surface of the water as much as 1 meter in height. The leaves are 10–20 cm across, and float above the water surface. It causes practical problems for marine transportation, fishing, hydro power and irrigation schemes. It is now considered a serious threat to biodiversity.

Briquetting makes these wastes easier to transport, to handle and to store. It is efficient to use briquettes as an alternative fuel to coal, and additionally this reduces the volume of polluting gases such as sulphur (S) and phosphorus (P) fumes. Increasing the material density through briquetting will increase the energy density. The briquettes are normally cylindrical in shape with a diameter of about 25- 100 mm and a length of about 40-400 mm. Briquettes can be produced with a density of up to 1.2 g/cm3 from loose biomass with a bulk density of 0.1 and 0.2 g/cm3. When using these briquettes for energy purposes, the optimal density is between 0.9 and 1.2 g/cm3. The briquettes are also affected by the moisture content. Briquettes with a moisture content of less than 18% are constant and durable. The maximum moisture content of wood pellets according to DIN 51731 is 12%. There are three types of briquetting:

Low Pressure Briquetting	-	< 5 Mpa
Medium Pressure Briquetting	-	5 to 100 Mpa
High Pressure Briquetting	-	>100 Mpa



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In this work, we have optimized the die for getting continuous and smooth output on low pressure screw type briquetting machine and compare the output with the high pressure piston type briquetting machine output.

II. REVIEW OF LITERATURE

Efforts are underway all over world, including countries like Nigeria, India, Indonesia, Ukraine, to remove water hyacinth from waterways by hand, machine, using chemical and biological control. Due to its fast growth and the robustness of its seeds, the water hyacinth has since then caused major problems in the whole area, e.g., a reduction of fish. Other effects of the fast growth are physical interference with fishing, obstruction of shipping routes and losses of water in irrigation systems due to higher evaporation and interference with hydroelectric schemes and increased sedimentation by trapping silt particles. It also restricts the possibilities of fishing from the shore with baskets or lines and can cause hygienic problems [1].

Instead of investing more amount on controlling the growth of water hyacinth on above areas, it is preferred to convert the waste into wealth by making biomass content available in the plant [2]. Various uses are been developed for the plant such as for making bio-fertilizer, furniture, sewage and biological waste-water treatment, and biogas production. Other uses include, feed for livestock, substrate for mushrooms and as vegetable for humans [3].

In India particularly in Tamil Nadu, the water hyacinth is available in phenomenal amount in rivers, canals, ponds etc. (Bhavani, Cavery, Kaligarayanpalaym canal etc.). The barrage power houses located on Cauvery river from Mettur to Erode are heavily affected by water hyacinth during power generation which requires high investment in removal. Various methods have been tried to control the growth in nearby areas of power plants and fishing zones by manual methods, machines and non-toxic chemicals.

In India, the **North Eastern Development Finance Corporation** (**NEDFi**), Assam, took the initiative to popularize the use of Water Hyacinth for making handicraft products. To further extend its usefulness as a renewable source of energy, the plant can be processed into biomass briquettes for heating purposes. A pilot study carried out in Nigeria shows that the briquette prepared from Water Hyacinth has the potential usage in cooking purpose [4].

In this context, biomass appears to be an attractive energy resource because it is a domestic and environmentally sound renewable fuel. Around 25% of agricultural residue wasted every year and Water hyacinth which is considered as the weed in the Water Resource can be effectively utilized by making fuel Briquettes i.e. Wealth from Waste.

III. MATERIALS AND METHODS

WATER HYACINTH PROCESSING

The fresh Water Hyacinth leaves have been collected from the Bhavani river and bhavani kattalai barrage. The collected fresh leaves are spread on the terrace of Mechanical department block to get removed of moisture. After drying of about 7 days the weight has been reduced to $1/4^{\text{th}}$. The dried leaves are pulverized into grain size of $5\mu m - 1mm$ by means of chopping in Grinder and Flour mill. The dried leaves should be immediately pulverized to avoid moisture absorption.



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Fig. 1 Water Hyacinth grown on Bhavani River

The powdered leaves are stored in the air tight container to avoid pollution and moisture absorption. Because, water hyacinth is very sensitive to atmospheric moisture and water particles. Hand sieving is a simple technique for separating particles of different sizes. Coarse particles are separated or broken up by grinding against one-another and screen openings. In this work briquette samples are prepared in low pressure briquette machine with dry leaves and with moisture content 8 to 16 wt (%).



Fig. 2 Powdered leaves stored in Zip Cover

DESIGN AND FABRICATION OF SCREW TYPE BRIQUETTING MACHINE

The screw press is a type of mechanical press machine. The earliest development work on screw presses was carried out in the USA in the 1930's [5]. In 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 occurs. If the die is not heated, then the temperature may not rise sufficiently to cause lignin flow and binding materials may have to be added. These can be molasses, starch, or some cheap organic materials. The briquettes from screw machines are often of higher quality than from piston units. The screw press is usually sized in the range 75-250 kg/h, though larger machines are available.



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Fig.3 Low pressure screw type Briquetting Machine

The major components of a Screw type briquetting machine are conical screw, Barrel, Hopper, Die block, gear box, Motor, Base stand.

Conical Screw: The screw was made with three sections as feeding, Transition and Metering in Mild Steel. The Screw was made conical to increase pressure throughout the length. The feed section will carry the material fed via the hopper forward towards the metering section for the pressure development. The screw was made by welding the profile on tapered screw. The dimensions of screw are shown in Fig 4.



Fig 4 Conical Screw

Barrel: The barrel was made of Mild Steel with a clearance of about 1mm to the conical screw. The barrel provides the backpressure for briquetting throughout the length. The dimensions of barrel are shown in fig 5.



Fig. 5 Barrel



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Base Stand: The entire set up has been mounted on the base stand with the adjusting base screw. The stand holds a 3Hp motor at the bottom and gear box at the top horizontally along the barrel, Screw and Die. The dimensions are given in Fig. 6.





Hopper: The hopper has been made with G.I sheet metal with a volume of 4.75 lit. The Hopper was fit on the barrel having an opening in the shape of ellipse. The dimensions are shown in fig.7.



Fig. 7 Hopper

Gear Box: A Worm and Worm wheel gear box with a speed reduction of about 20:1 from the motor driving pulley to driven pulley of gearbox input shaft .it reduces the speed from 1440 rpm to 120rpm to the conical screw.

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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Fig. 8 Initial Die

Inference: It is found that the inlet diameter of the die (\emptyset 38 mm) is less than the exit diameter (\emptyset 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	Maximum	density $-\frac{1302}{4}$ - 4 34	
compaction ratio	— Initial d	lensity $=$ $\frac{300}{300}$ $=$ $\frac{100}{300}$	



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

Modification II:

Entry diameter = 50 mm, Exit diameter = 30 mm
Taper angle =
$$5.19^{\circ}$$
, Compression ratio = $1: 6.25$
Compaction ratio = $\frac{Maximum \ density}{Initial \ density} = \frac{1104}{300} = 3.68$



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Fig. 10 Modified die design II

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:



Fig. 11 Modified die design III

Entry diameter	= 50 mm,	Exit diameter	= 30 mm
Taper angle	= 5.71°,	Compression ratio	= 1: 5.25
Compaction ratio =	Maximum density	$-=\frac{1190}{2}=3.966$	
compaction faile	Initial density	300	

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: 6.66Compaction ratio = $\frac{Maximum \ density}{Initial \ density} = \frac{1051}{300} = 3.50$



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Fig. 12 Modified die design IV

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 , Taper angle = 2.1°, Compaction ratio = $\frac{Maximum \ density}{Initial \ density}$ = $\frac{915}{300}$ = 3.5



Fig. 13 Modified die design V

Force Pressure developed in screw & barrel, P₁ Area $\frac{341.04}{100}$ N/m² 2π rh 341.04 = $\overline{(2\pi \times 0.016 \times 0.1) + (2\pi \times 0.012 \times 0.315)}$ $= 142428798.86 \text{ N/m}^2$ (::1Pa= N/m²) $P_1 = 1.42 \text{ MPa}$ Pressure Developed in Die, $P_2 =$ Α 341.04 = - $\pi \times 0.0215^2$ $= 234843.49 N/m^2$

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P2 = 0.234 MPa

Total Pressure developed, $P = P_1 + P_2 = 1.42 \text{ MPa} + 0.234 \text{ MPa} = 1.654 \text{ MPa}$

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.

Finally the samples are taken from the optimized die and various tests are conducted as follows.



Fig. 14 Low pressure screw type briquetting machine and briquette samples

IV. RESULTS AND DISCUSSION

Bulk density test:

The ASAE Standard ASAE S269.4 DEC96 provides a simple procedure for measuring the density of briquettes. *Procedure*: Weigh briquette in an analytical balance. Record the weight in grams, Place briquette in a sealed plastic bag, Prepare a graduated container where the briquette may be immersed. Fill this container with two-thirds full of water. Record the initial volume of water. Immerse the briquette in the container until it is 50 mm below the water surface. Record the volume of water with the briquette immersed. Density is calculated using the following formula: Volume of briquette (V_f -V_i) = Mass /Density.



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Fig. 15. Density Vs Compression ratio

Inference: Higher the compression ratio has direct imposed effect on the density of the briquette. However higher density increases the compressive strength, it also has negative impact of blocking of briquette inside the die block. From the die block optimization it is found that the compression ratio and the maximum density are directly proportional i.e. if the compression ratio is increased, the final density of the briquette also get increased.



Density with different moisture content:

Fig, 16 Density Vs moisture

Inference: The density of the briquette has more sensitive to the moisture content. So that the powdered biomass were at initial stage itself kept in air sealed bags. And also the density for various samples with different moisture contents (8%, 10%, 12%, 14% and 16%) were measured. Thus the results show that the wt.12% of the moisture content is the best sample which produces high density (915 kg/m³) among other samples.



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Calorific Value Test:

Few samples of Water Hyacinth Briquettes has been select and given for calorific value determination in Italab Salem Private Limited [2]

Low pressure Briquette sample Calorific value (At 16 bar)

As per the literature, higher density briquette sample must have higher calorific value. So that the higher density sample (12 % of wt. moisture) was tested for gross calorific value.

1.	Gross Calorific value (On dry basis)	3625 kcals/kg
2.	Gross Calorific value (as on basis)	3208 kcals/kg

High Pressure Briquette Sample Calorific values (At 100 Bar) [6]

1.	Gross Calorific value (On dry basis)	3601 kcals/kg
2.	Gross Calorific value (as on basis)	3240 kcals/kg

Inference: The low pressure screw type briquetting press produced briquette has the calorific value equivalent to the high pressure hydraulic type briquetting press produced briquettes. The advantage of the low pressure screw type briquetting machine over high pressure briquetting machine is the continuous and smooth throughput. And also there is no change in the burning characteristics.

V. CONCLUSION

- Low Pressure Screw type briquette machine was designed and proper material selection was done.
- For the drive motor of 3 hp capacity, the machine can produce a water hyacinth briquette at minimum pressure of 16.5 bar and compaction ratio of 3.05
- Moisture content for obtaining stable biomass briquettes is 10-12%. More than this moisture content leads to lower the densification and strength.
- The Calorific value obtained from the low pressure method is 3208 kcals/kg which is equal to the high pressure method briquette (100 bar) 3240 kcals/Kg.
- The densities of briquette made from both the methods are found equal, so that the strength of the briquettes will not change that's also were tested.
- Hence, it is concluded that Water Hyacinth Briquettes made by low pressure screw type briquetting method gives equivalent result as high pressure ram type briquetting method. And it is having high potential for cooking and industrial use.

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