Design and Development of a Compact Screw-Press Biomass Briquetting Machine for Productivity Improvement and Cost Reduction

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Abstract

This paper presents a design and development of a compact screw-press briquetting machine which combines three functions including crushing, mixing and briquetting in a single unit. By eliminating individual machines, the great savings in space, material handling and worker, and the improved efficiency can be realized. This technology also helps to reduce cost and production time, and improve productivity, and eventually lead to be able to survive in competitive environments. This paper also presents characterizing property of the briquettes produced by the developed machine. Finally, a cost analysis for the compact briquetting machine is presented.

Keywords*:* Compact biomass briquetting machine, productivity improvement, cost analysis.

1. Introduction

Due to the present world's energy crisis and its related environmental issues as well as increasing trend of fossil fuel prices, renewable energy source is an essential matter. Biomass briquettes are a renewable source of energy and they avoid adding fossil carbon to the atmosphere. They are made from agricultural waste and are a replacement for fossil fuels, and can be used to heat boilers in manufacturing plants, and also have applications in developing countries.

To survive in competitive environment, biomass briquette entrepreneurs should be provided an appropriate technology which helps to reduce production cost and time, and improve productivity. Therefore, in this paper we provide a compact biomass briquetting machine which combines three functions including crushing, mixing and briquetting in a single unit. By eliminating individual machines such as crushing, mixing and briquetting machine, the great savings in space and efficiency can be realized while maintaining an output quality with low cost.

This paper is organized as follows: In the first section, we describe overview of briquetting process. In the second section, we describe the design and development of a compact briquetting machine. Finally, we provide a comparison of the result of production between the new system (a compact machine) and the

existing system (three individual machines working together).

2. Briquetting Process Overview

Briquetting process is a process of compaction of residues into a product of higher density than the original raw material. In developing countries such as Malaysia, Philippines, and Thailand, biomass briquettes are mostly carbonized to obtain briquetted charcoal [1]. The briquette carbonization production process consists of a carbonization stage and a compaction stage.

In the carbonization stage, a biomass material such as wood is heated (approximately 450 ^{O}C) but is not given enough oxygen for the material to burn. This stage produces charcoal. In compaction stage, the charcoal is crushed into very small size as a carbonized powder. Then the powder and some binder are completely mixed at a predetermined mixing ratio. After that the mixture is brought into the molding machine to form the briquettes. The briquettes are dried and cooled. An overview of the process flow is shown in Fig. 1.

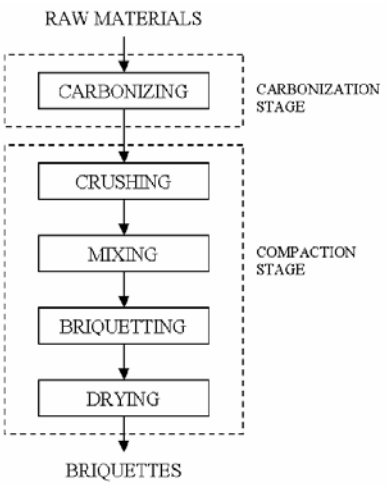

Fig. 1 Biomass briquetting process

Each step of the process is detailed as follows:

Carbonizing: The raw material is carbonized by less air combustion in carbonization furnace with low temperature approximately 450^{O}C.

Crushing: Carbonized material is crushed into very small size by using crushing machine.

Mixing: Appropriate proportions of raw materials and binder are mixed thoroughly into the mixing container

Briquetting: The mixture is pressed or produced into finished products. Briquetting machine is used for briquetting charcoal fine into charcoal briquettes [2].

Drying: The briquettes were dried under sun light.

The important manufacturing process of the charcoal briquette production is crushing, mixing and briquetting, which requires three machines in the production process. This research is to develop a biomass briquetting machine which includes crushing, mixing and briquetting process in a machine. In this way, production area and production cost of biomass briquettes can be reduced by using the newly designed machine. It is a simple energy and money saving device made out of locally available materials.

There are several methods available for briquetting biomass. In developing countries, the well-known briquetting method that is suitable for small-scale applications is the screw-press briquetting. The raw material from the hopper is conveyed and compressed by a screw in the briquetting machine. This process can produce denser and stronger briquettes compared with piston presses [3].

3. Methodology

This methodology is divided into four sections including design of a compact briquetting machine, developing machine, characterizing the property of the briquettes and cost analysis of the new system.

3.1. Design of compact briquette machine

In this paper, the compact briquetting machine has been designed with the aim of eliminating individual machines, reducing material handling, manpower and space, and improving productivity. The important matter is that the obtained briquette quality should be in an acceptable range.

We design the compact screw-press biomass briquetting system which combines three functions including crushing, mixing and briquetting in a single unit as shown in Fig. 2. The briquetting machine designed has a capacity of about 90 kg/hr and is driven by a 5 HP electrical motor.

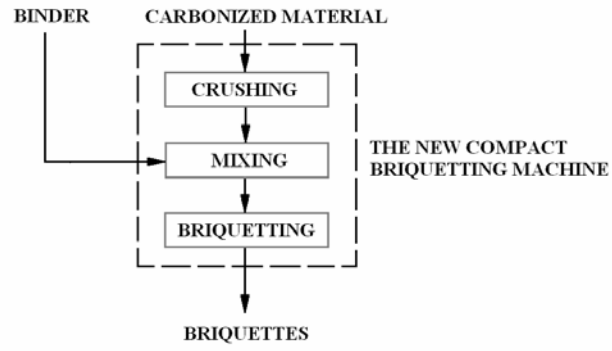

Fig. 2 The new compact briquetting machine as a single unit

Let us describe about the existing/traditional and the new system of briquette production.

The existing briquetting system (three individual machines working together, including rushing, mixing and briquetting machine and three workers): carbonized material is transferred to a crushing machine which has a hammer mill for grinding and crushing the carbonized, the fined charcoal and binder are completely mixed at a predetermined mixing ratio and then transferred to a briquetting machine to be extruded into briquettes. After that the briquettes are cut and dried before sending to its store.

The new briquetting system as the proposed design (a compact machine and one worker): carbonized material is transferred to a compact machine and then the binder is added into the mixing container. Briquettes are extruded out at the die exit. Finally, the briquettes are then cut and dried before sending to its store. In doing so, it helps to reduce worker, material handling, transfer time, space and production time. That leads to improve its productivity.

3.2. Developing machine

Crushing system: hammer mill (see in Fig. 3) is used to crush carbonized material into carbonized powder. Carbonized powder is then sieved during grinding, at 1.13 kg/min. Size of carbonized powder obtained from this system is less than 1.7 mm.

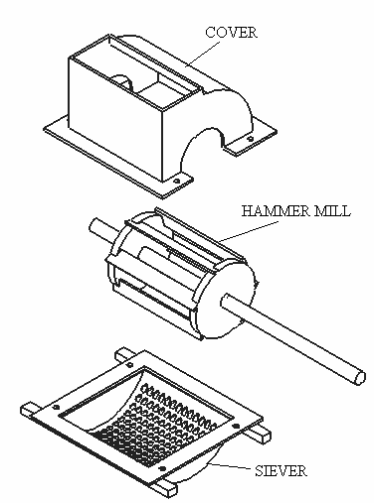

Fig. 3 Crushing system

Mixing system: Carbonized powder and cassava starch as a binder in this study are mixed homogeneously by rotating stirrer in a container (See Fig. 4). After that, the mixed material is then sent into a briquetting process.

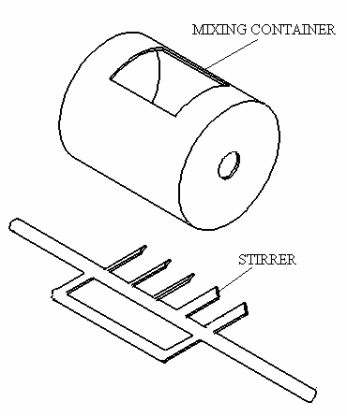

Fig. 4 Mixing system

Extrusion system: In a briquetting process, the mixed material is extruded by a screw extruder [4], [5] which acts as a continuous feeder and driven by motor. The volume of the material is decreased as it is transferred from the hopper to the die exit. This is achieved by decreasing the diameter of the threaded shaft and cylinder gradually starting with a uniform diameter at the feeding position and decrease gradually to a minimum value at the die position [6]. Figure 5 shows the design of the screw.

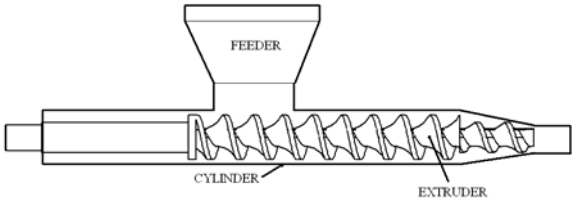

Fig. 5 Extrusion system

The new compact briquetting machine assembly is shown in Fig. 6.

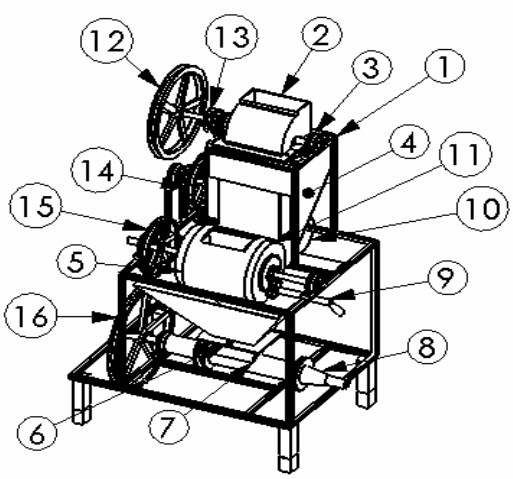

Fig. 6 The new compact briquetting machine assembly

Table. 1 Part of the machine

Item No.	Part Name	Amount
1	Structure	1
2	Crushing system	1
3	Bearing	7
4	Charcoal fine chamber	1
5	Mixing cover	1
6	Cylinder	1
7	Feeder	1
8	Extruder	1
9	Mixing handle	1
10	Motor	1
11	Mixing container	1
12	Crushing pulley, size 16 inch	1
13	Pulley, size 4 inch	2
14	Pulley, size 10 inch	1
15	Mixing pulley, size 10 inch	1
16	Extruding pulley, size 18 inch	1

After finishing the development of such a machine, the capacity and functional testing of the machine are performed. In testing, the briquettes are produced continually by the machine fabricated at full capacity and an appropriate ingredient ratio of the mixture is 50% carbonized powder, 40% cassava starch and 10% water.

It is found that the machine can produce the briquettes at production rate of 0.9 kg/min, the energy consumption is 41.6 kWh/Tonne. It is also found that the machine can work appropriately as designed.

3.3. Characterizing property of the briquettes

Heating value: According to the ingredient ratio, the test was conducted to study the heating value. It was found that the heating value of briquettes obtained from this machine is approximately 5,200 calories per gram which meets the community product standard of Thailand.

3.4. Cost analysis

In cost analysis, charcoal [7] is used as raw material which is available in dry form and does not require drying but needs grinding prior to briquetting.

In cost analysis for charcoal briquette production by using a new compact briquetting machine and one labor, it is assumed that the compact briquetting machine have a useful life expectancy of 5 years, the operating time at 8 hours a day, 250 days in a year, direct labor cost per day is 250 THB/labor, electricity cost of 3.5 THB/kWh, total electrical input power is 3.75 kW, briquette price is 5 THB/kg, raw material cost and transportation cost is 2 THB/kg. Price of the compact briquetting machine is approximately 40,000 THB. The first investment is 190,000 THB including the storehouse and machines. The machine capability is approximately 90 kg/hr. Results from the analysis show that, payback period for the production is approximately 5.21 months and the Internal Rate of Return (IRR) is 216%.

4. Comparison Between the Existing and the New System

Comparison of the production results between the existing/traditional system (three individual machines working together and three workers) and the new system (a compact machine and a worker) at the same conditions such as using a 5 HP electrical motor and using screw-press technology. (See Table. 2)

Table. 2 Comparison between the existing and the new system

		The Existing System	The New System
1.	Worker required (man-day)	3	1
2.	Productivity (Tonne/day)	0.58	0.72
3.	Operating cost (Bth/Tonne)	3,554	2,782
4.	Area required (m^2)	48	16

Fig. 7 Briquettes obtained from the compact machine

5. Discussion

According to design and development of the compact briquetting machine and the results of the functional and capacity testing, it found that the compact briquetting machine can work functionally and properly with the obtained briquette quality is in an acceptable range.

The comparison between the new and the existing system shows that a lot of improvement occurred in the new system such as the process time, worker and production area required, operating cost, and productivity. It is so because combining three functions in a single unit and the machine can operate continually can help to reduce the transfer time and distance, and material. The new system just needs one worker to operate the compact

machine and convey the material. That leads to reduce cost and improve the productivity of the system.

The new compact machine has potential to replace the individual traditional machines in the biomass briquetting industry due to the lower price of the compact machine and its short payback period.

6. Conclusion

The compact biomass briquetting machine fabricated for this research is a prototype unit. The compact machine which combines three functions including crushing, mixing and briquetting in a single unit is able to improve the production cost and productivity. From comparison between the new and the existing/traditional briquetting system, it was found that when using the compact briquetting machine, the required production area, production time and operating cost are reduced by 67, 16, and 22% respectively when using the compact machine. Furthermore, the investment in producing biomass briquette by using the compact briquetting machine, based on mentioned conditions, is economically attractive also with payback period of 6 months and the Internal Rate of Return of 216%.

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