ORIGINAL ARTICLE

Automated Screw Type Briquetting Machine as A Small Business Venture

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Abstract: This study aims to develop an automated screw briquetting system that will be applicable as a small business venture in provincial areas of the Philippines. The existing manual briquette machine was integrated with automation equipment and software to facilitate continuous briquette production. The automated machine uses an induction motor fitted with a Variable Frequency Drive to control the motor's rotational speed. A Programmable Logic Controller was used to facilitate the overall control of the briquetting system through the synchronization of the sensors and drivers. In addition, the machine features a band heater with a temperature controller and a control panel for safety and ease of operation. A simulation was performed to determine the optimal design configuration of the screw geometry applicable for automation. Experiments were performed by varying the temperature and screw speed to achieve optimal briquette quality. The automation results showed that briquettes of high quality can be produced at a rate of 10kg/hr. An economic feasibility study was done to show the machine's viability in a provincial small business context.

Keywords: automation, briquetting, screw type, business

Introduction

Rice hull is a major agricultural waste product in the Philippines. However, due to its low bulk density, rice hull must be further processed thorugh carbonization and briquetting to produce a useful product. Briquetting of rice hull entails considerable handling, transportion and storage costs.

A Bangladeshi design of a screw press briquetting machine used mild steel for screw fabrication and cast iron for the die. To drive the screw to compress the feedstock the design used a 27 hp diesel engine running at 2200 rpm and a 20 hp electric motor. (Md. Nawsher Ali, 2004). A similiar design was produced in Vietnam but used a different prime mover (SIDA, 2005). A Thai design for a Screw Press Briquetting Machine incorporates crushing, mixing and briquetting functions into a single machine, thus improving productivity and reducing material handling, man power and space requirements. (Teerapot Wessapan, 2010).

The Philippines Department of Science and Technology produces a screw-type briquetting machine based on a modified meat grinder, and is available in some provinces. However, manual operation makes its use tedious and labor intensive, and the system could benefit from automation.

In this study, a new screw geometry for the briquetting machine was used to improve briquette compression. The machine was also automated using a programmable logic controller which controls all the electronic devices used. The automation of the briquetting machine will help increasing the briquette production rate and thus provide improved productivity for small-scale briquette manufacturers in rural areas of the Philippines.

Methodology

Machine Design

For the computer aided design and simulation phases, Solidworks was used for the design and mechanical simulation of the mechanical framework of the automated briquetting machine. Multiple designs and simulations were performed prior to fabrication. It is imperative that the design and automation plan be approved based on the cost of materials and availability of components.

Figure 1(a) shows the final mechanical assembly of the briquetting machine with the following main components: screw extruder, hopper, main casing, die, and machine frame. The bottom area of the machine frame houses the machine's prime mover (a Mitsubishi GM-D geared motor) which is coupled to the briquetting screw shaft via a chain drive.

Mild steel is used to fabricate the screw, casing and die. Other components such as the geared motor, chain transmission set-up and bearing units were commercially available. The proposed design varies in terms of screw geometry. To exert added compaction, the screw end is tapered to match the tapered geometry of the corresponding die.

The automated briquetting machine is shown in Fig. 1(b). The machine can be activated using a control panel from which the briquetting process will be automatically implemented. A heating band was also installed in the body of the briquetting machine to adjust system temperature to improve briquetting output.

Given the large dimensions of the screw, it could not be fabricated using a lathe machine, but was rather machined using a milling machine augmented with an indexing head or universal dividing head as shown in Fig. 2.

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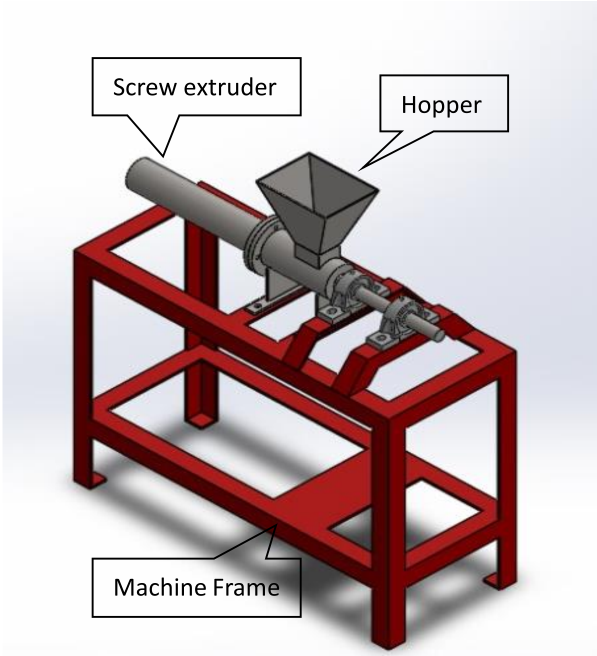
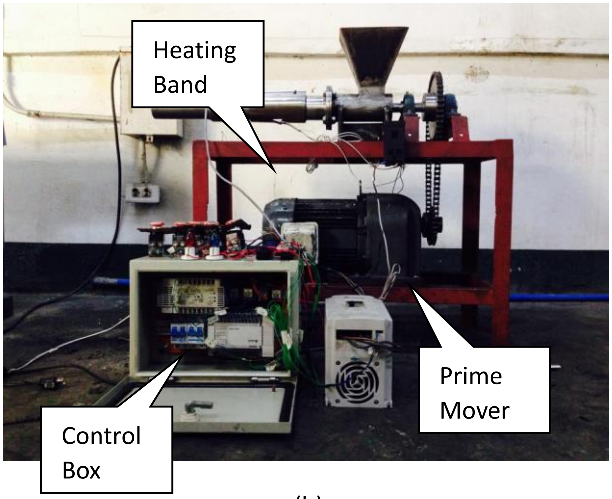


(a)



(b)

Figure 1. (a) Briquetting machine mechanical assembly (b) Automated briquetting machine.

Figure 2. Screw Extruder.

Electrical and Automation Components

Figure 3 presents a flowchart for the automation of the briquetting machine. The process starts with the algorithm conceptualization considering all the inputs and outputs necessary for system automation. Sensors and controllers were selected to facilitate the creation of the automated briquetting machine. A simulation of the ladder program using WPLSoft was implemented to verify the correctness of system logic. The program was revised until the outputs are realized.

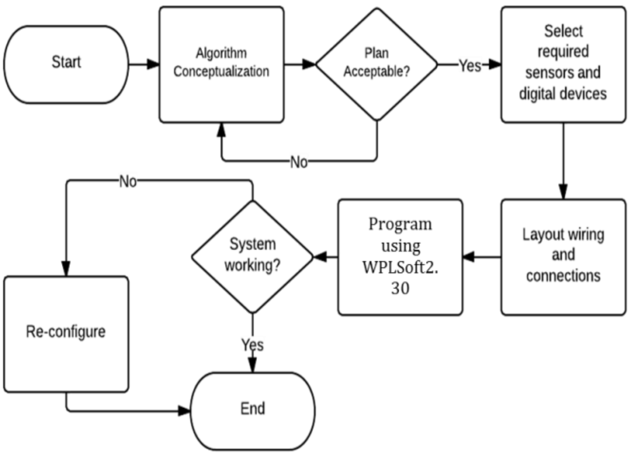


Figure 3. Flowchart for system automation.

All the electrical sensors and controllers were enclosed in a controller box as shown in Fig. 4. The control box contains a programable logic controller, relays and drivers to control the motor. This is then installed below the mechanical frame of the briquetting machine for easy access and modification

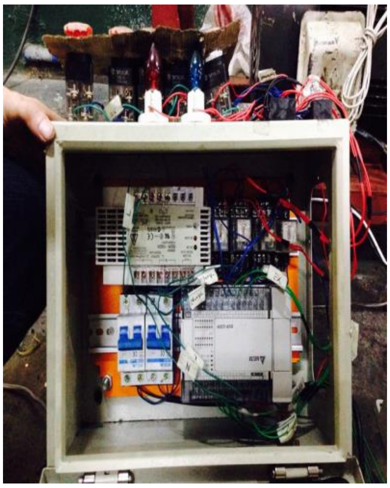


Figure 4. Electrical device control box.

Results

The performance of the automated briquetting machine was verified through the briquette formation test and the briquette quality test.

Briquette Formation Test

A briquette formation test was conducted to determine which combination setting of die heater temperature and screw speed would best compress carbonized rice hull into briquettes. The feedstock was prepared first. For each test run, 300g of carbonized rice hull was used. Following the binder mix ratio as recommended by the Department of Science and Technology, 15g of cassava starch was mixed with 150mL of water. From this, temperatures of 40, 60 and 80°C were tested with varying screw speeds. Briquette quality was inspected visually and judged in terms of the smoothness, cracking, and hardness.

Table 1 summarizes the results of the briquette formation test. The die heater's temperature directly affects the quality of briquettes produced by the screw-type briquetting machine, perhaps because it heats up both the carbonized rice hull and the binder, thus facilitating compression into the die. Table 1 also shows that at temperatures of 60°C and above, briquettes form well at different speeds. Figure 5 shows the briquettes formed by the machine.

Figure 5 Briquettes formed.

Table 1. Briquette formation test.

BRIQUETTE FORMATION TESTS				
TEMPERATURE SETTING (°C)	SCREW SPEED (rpm)	BRIQUETTES FORMED?		DESCRIPTION
		YES	NO	
40	60		×	Easily crumbles
	80		×	Easily Crumbles
	100		×	Did not compress
60	60	×		Soft, Brittle, Moist, Lots of Cracks
	80	×		Clay- like hardness, Moist, w/ Cracks
	100	×		Clay- like hardness, Moist, w/ Cracks
80	60	×		Hard, Dense, Smooth
	80	×		Hard, Dense, Smooth
	100	×		Hard, Dense, Smooth

Briquette Quality Tests

A drop test was used to determine the physical properties and impact resistance of the resulting briquettes. Each briquette sample was repeatedly dropped (maximum of five times) from a stationary starting point of 1 m height onto a steel plate until it fractured completely. Standard briquettes should be able to withstand at least three impacts (Chaiklangmuan, Supa,

& Kaewpet, 2008). Table 2 shows the drop test results which suggest that a die heater temperature of 80°C produces optimal briquettes.

A Water Boiling Test was performed to verify briquette flammability. It took an average of 2 hours to consume 120g of briquettes, for a burning rate of 11.53 g/min, suggesting that burning duration may be improved further through increased thickness or compressibility. A bomb calorimeter was used to determine the calorific value of the briquettes at 4,214 kcal/kg.

Table 2. Drop test results.

80°C DIE HEATER TEMPERATURE SETTING			
SCREW SPEED	IMPACT RESISTANCE		
RPM	SAMPLE 1	SAMPLE 2	SAMPLE 3
60	3 out of 5	2 out of 5	3 out of 5
80	3 out of 5	3 out of 5	3 out of 5
100	4 out of 5	5 out of 5	5 out of 5

Economic Feasibility

An economic feasibility study was conducted to determine if the screw type briquetting machine could be applicable to small scale business. Table 3 shows the production data of the automated machine. The calculations assume a production rate of 10.50 kg/hr and an initial capital investment of Php123,000 for the automated machine. Workin0g 8 hours a day, 24 days a month, the capital investment can be recouped in 1.60 years, producing an annual return on investment (ROI) of 62.47 percent.

Table 3. Automated machine production data.

	PhP	Unit
Price of Briquette	18.00	Php/kg
Production Rate per hour	10.50	kg/hr
Production Rate per day	84.00	kg/day
Gross Income	1512.00	Php
Total Daily operating Expense	1245.19	Php
Net Income	266.81	Php
Working Days per Month	24.00	days
Working Days per Year	288.00	days
CALCULATED		
Return of Investment per annum	**62.47**	**%**

Conclusion

The screw-type briquetting machine developed in this study produced briquettes of a quality at par with those available in the local market. Automating the briquetting machine achieves a production rate of 10.5 kg/hr. Furthermore, capital investment can be recouped within 1.6 years, and the machine produces an annual ROI of 62.47%, making it suitable for small businees ventures in the Philippines.

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