A study on improved biomass briquetting

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1. Introduction

A regional research and dissemination programme, "Renewable Energy Technologies in Asia", funded by the Swedish International Development Cooperation Agency (SIDA) and coordinated by the Asian Institute of Technology (AIT), was being executed in six Asian countries during 1996-2001 on biomass briquetting, which is one of the research areas under the programme. Research and dissemination activities are being carried out at AIT as well as three participating country institutions. The main objective of briquetting research at AIT is to develop improved heated-die screw-press biomass briquetting systems by reducing the electrical energy consumption by pre-heating biomass, heating the die of the briquetting machine by means of a briquette-fired stove and by incorporating a smoke removal system. This paper presents the experimental data on rice-husk briquetting with and without pre-heating and also details the design and operating parameters of a die-heating stove, which was used to replace the electrical coil heaters, to reduce the net electricity consumption.

2. The briquetting system

Utilisation of agricultural residues is often difficult due to their uneven and troublesome characteristics. The process of compaction of residues into a product of higher density than the original raw material is known as densification or briquetting. Densification has lately aroused a great deal of interest in developing countries all over the world as a technique for upgrading of residues as energy sources. Converting residues into a densified form has the following advantages.

- The process increases the net calorific value per unit volume.
- The densified product is easy to transport and store.

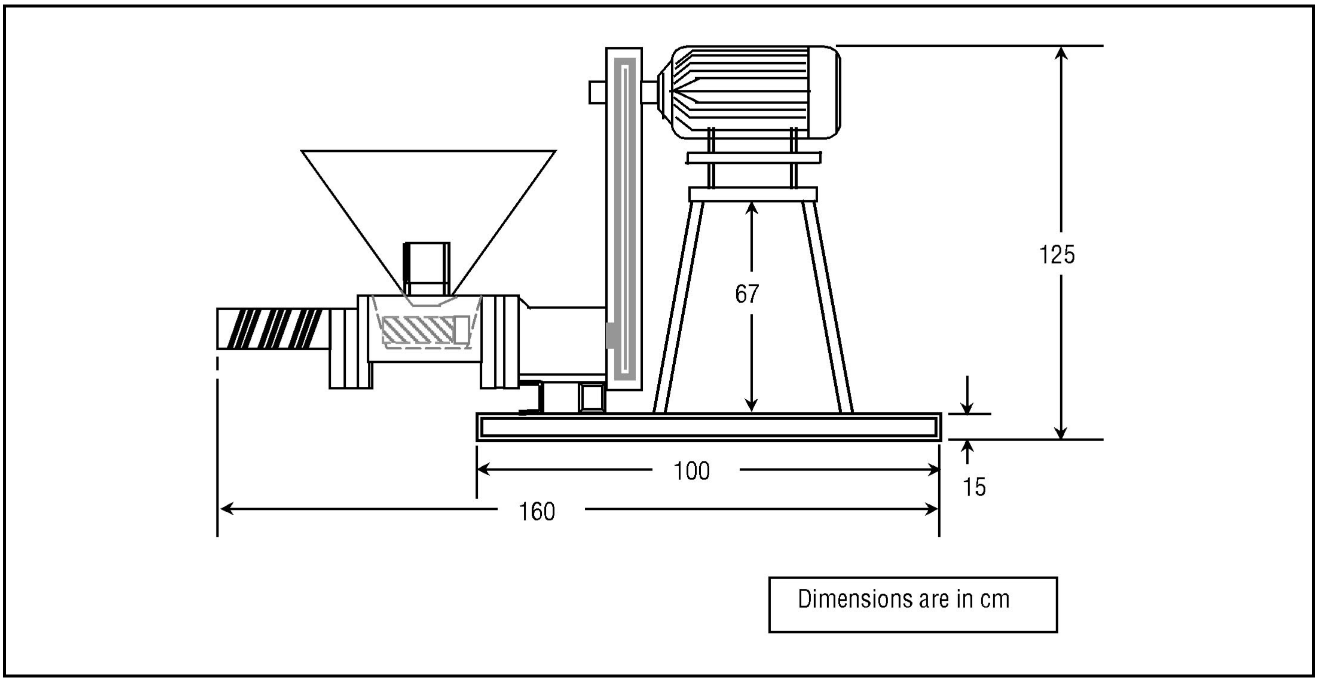

Figure 1. The heated-die screw-press type briquetting machine used for the experiments

- The process helps to solve the problem of residue disposal.
- The fuel produced is uniform in size and quality.

The process also helps to reduce deforestation by providing a substitute for fuel-wood.

There are several methods available for densifying biomass. Screw-press briquetting is a popular densification method suitable for small-scale applications in developing countries. The raw material from the hopper is conveyed and compressed by a screw in screw-press briquetting. This process can produce denser and stronger briquettes than those produced by piston presses. There are basically two types of screw press: conical screw press and screw press with heated die.

It has been reported that pre-heating the raw materials reduces the power required for the briquetting, allows higher quality briquettes for given energy input, lowers wear on dies or a combination of these [Joseph et al., 1985; Reed et al., 1980]. Reed et al. [1980] found that the work and pressure of compression or extrusion can be reduced by a factor of two by pre-heating the raw material to 200-250ºC before densification.

Joseph and Hislop [1985] reported the results of briquetting preheated papyrus by the Intermediate Technology Development Group (ITDG). Papyrus briquettes were produced at pressure between 25-30 MPa with pre-heat, compared to a pressure of approximately 180 MPa without pre-heat. The authors concluded that existing briquetting plants modified for pre-heat should operate at lower pressures, wear rates and power requirements.

Aqa and Bhattacharya [1992] studied the effect of varying the die temperature and the raw material (sawdust) pre-heat temperature on the energy consumption for sawdust using a heated-die screw press. Densifying sawdust pre-heated to a suitable temperature could save a significant amount of energy. The energy input to the briquetting machine motor, die-heaters and the overall system were reduced by 54.0, 30.6 and 40.2 % respectively, in the case of sawdust pre-heated to 130ºC.

Performance tests of a Shimada (Europe) briquetting machine in India showed that raising the feed temperature to 80-90ºC before briquetting increases screw life to 44 hours from 17 hours without pre-heating [Mishra, 1996]. Also, the production rate was found to increase from 340 to 360 kg/hr and the power consumption was reduced by 15-20 %.

3. The heated-die screw-press briquetting machine

The briquetting machine used in the present study was of single extrusion heated-die screw-press type (Figure 1). The major parts of the machine are a driving motor, screw, die, die-heaters and power transmission system. A pulley and belts were used to transmit power from the motor to the screw. An electrical coil heater was fixed on the outer surface of the die, to heat it to about 300ºC. This temperature is required to soften the lignin in the biomass, which acts as a binder. The electrical heater was thermostatically controlled, to maintain the temperature at all times. When the motor is started and raw material is fed to the screw, it gets compressed and extruded through the die.

The cylindrical die has, lengthwise on the inner surface, five grooves which serve to prevent the densified material from rotating with the screw. The briquettes often get partially pyrolysed at the surface and hence there is quite a lot of smoking during briquetting. The design of the screw results in the formation of a central circular hole in the briquette; this acts as an escape route for steam formed during briquetting.

The briquetting machine had a capacity of about 90 kg/hr and was driven by a 20-hp (1 horse power or hp = 746 W) electrical motor.

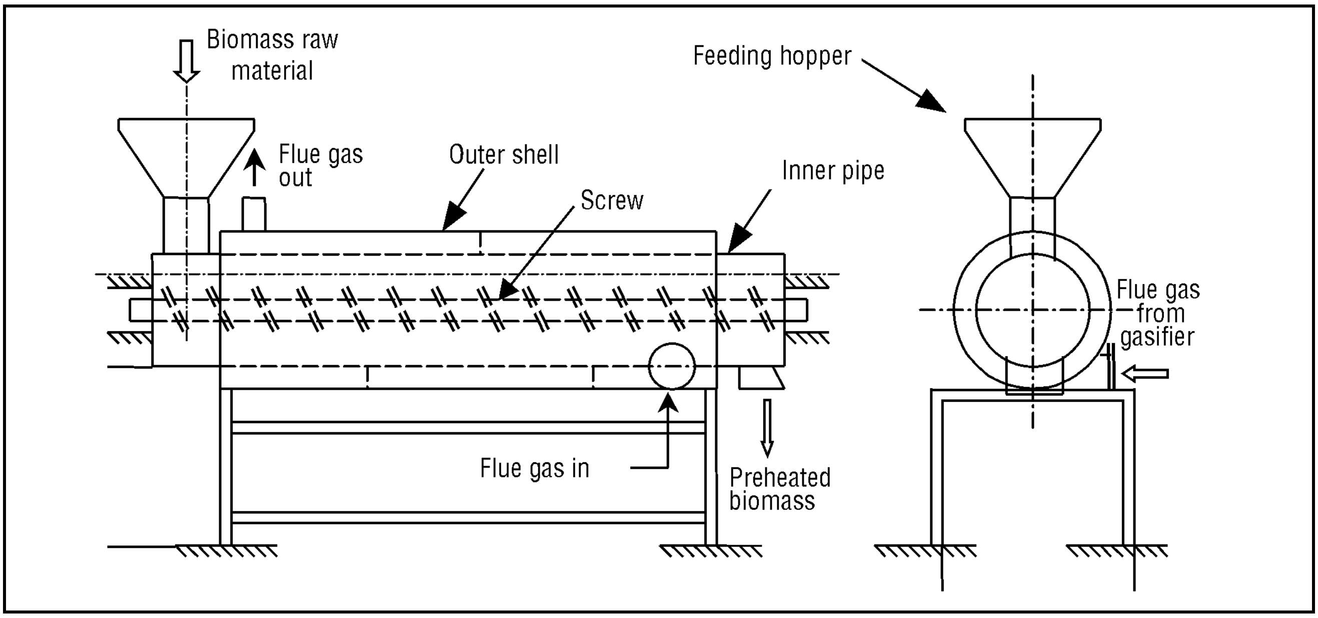

Figure 2. The rice-husk pre-heater

The major maintenance problems of this briquetting machine are due to the wear of the screw.

4. Biomass pre-heating setup

The biomass pre-heater is essentially a shell-and-tube heat exchanger. Biomass is passed through the "tube" by a motor-driven screw feeder, while hot flue gases from a biomass gasifier pass through the "shell". The temperature of the flue gases could be controlled by mixing cold air with the hot gases. Rice-husk was fed to the pre-heater when the gas temperature reached about 650ºC.

The raw material pre-heating system consisted of a gasifier, a gas combustion chamber, an air-flue gas-mixing chamber and the pre-heater. The gas from the gasifier was burned in the combustion chamber. The hot flue gas from the combustion chamber, diluted/cooled by mixing with fresh air if necessary, was used to heat the raw material in the pre-heater.

The gasifier was of downdraft type and used charcoal as fuel. It was 1.4 m tall and around 15 kg of charcoal could be loaded for one batch, which could run for about 10 hours continuously. The gasifier consisted of a hopper for fuel storage, a reactor zone, a grate and an ash-pit. The reactor part of the gasifier was made of stainless steel and was insulated by ceramic fibre insulation to reduce heat loss. A blower was used to supply air to the gasifier. A suction blower was connected to the outlet side of the gasifier for start-up. The producer gas leaves the gasifier through a pipe connected below the grate. The producer gas and air were supplied to a combustion chamber.

The combustion chamber was located between the gasifier and pre-heater to burn the producer gas. It was insulated internally by fireclay and externally by ceramic fibre insulation. A sight glass was provided to watch the combustion process. Air was supplied to the combustion chamber by a blower to burn the producer gas. An electrical heater placed inside the combustion chamber was used to ignite the producer gas. A mixing chamber was used to cool down the flue gas if necessary before its entry into the pre-heater. This was achieved by mixing fresh air with the hot flue gas in this chamber. Fresh air was supplied to the mixing chamber by a blower.

The pre-heater was designed and constructed to heat the raw material before feeding to the briquetting machine. The pre-heater (Figure 2) was 2.3 m long and 40 cm wide and consisted of an outer shell and an inner pipe (feeder drum). The raw material was pre-heated while being conveyed through the feeder drum by means of a conveyor screw. The pre-heater screw was rotated by a variable-speed motor. The hot flue gas from the combustion chamber was passed through the space between the feeder drum and the shell and discharged to the atmosphere. Thus, the feeder drum was heated by the flue gas at the bottom. The outer shell was insulated by a 5-cm thick layer of rock-wool to reduce heat loss to the surroundings. The pre-heater exit point was so adjusted that raw material was fed directly to the briquetting machine.

The speed of the pre-heater screw feeder was selected on the basis of the required biomass flow rate into the briquetting machine. Electrical energy consumption by briquetting machine, die-heaters and pre-heater motor was recorded using watt-hour meters. Total mass of briquette produced during each experiment was weighed to calculate the production rate.

5. Biomass die-heating stove

The electricity consumption for die-heating of the briquetting machine constitutes a significant portion, around 25 %, of the total electricity consumption [Aqa, 1990]. Substitution of the electrical die-heaters by a biomass-fired stove is therefore expected to reduce briquette production cost by cutting down electricity cost.

After conducting extensive studies with a biomass gasifier stove and a simple stove, the latter was found to perform better, by offering the required steady die temperature. The stove (Figure 3) was of mild steel (1.5-

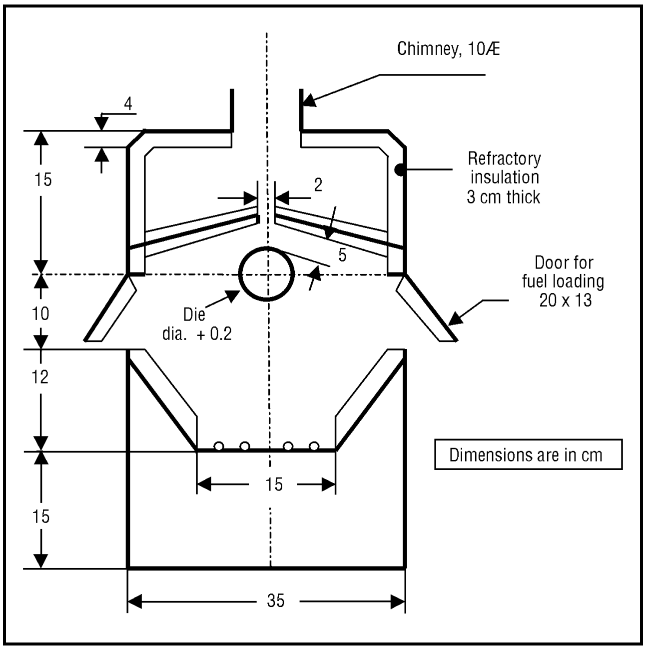

Figure 3. Die-heating stove for briquetting machine

Table 1. Briquetting without biomass pre-heating

Run no.	Average die temperature (ºC)	Briquette production rate (kg/hr)	Electricity consumption (kWh/kg)		
			Heater	Motor	Total
1	390	91.6	0.060	0.112	0.172
2	390	87.7	0.071	0.113	0.184
3	365	85.9	0.071	0.110	0.181
4	380	88.3	0.070	0.110	0.180
Average		**88.38**	**0.068**	**0.111**	**0.179**

Table 2. Briquetting with biomass pre-heating

Run no.	Average die temp. (ºC)	Average biomass temp. (ºC)	Production rate (kg/hr)	Electricity consumption (kWh/kg)		
				Heater	Motor	Total
1	390	100	82.2	0.058	0.094	0.168
2	370	115	81.2	0.053	0.105	0.165
3	390	130	80.0	0.045	0.097	0.150
4	390	140	84.5	0.052	0.101	0.161
Average			**82.0**	**0.052**	**0.099**	**0.161**

mm sheet) construction, with a furnace of 20 cm × 35 cm × 40 cm (w × b × h) volume and 2-m long chimney attached to it at the top. The die of the briquetting machine passes through the furnace, exposing its outer surface to the flames inside the furnace. The furnace was insulated with a 30-mm refractory lining on its inner surface. Doors were provided for loading the fuel as well as to remove the ash. An ash-scraper was fixed below the grate to remove from the furnace excess ash, which will fall through the grate.

Two steel baffles were fixed just above the die, to converge the flames towards the die surface. They were insulated on both sides using refractory cement. The baffles were found to improve the heat transfer from the flames to the die considerably.

Fuel (briquette pieces of size 40 × 40 mm size) was loaded through the side doors up to the bottom level of the die and ignited using some wood chips and kerosene. When the die temperature reached 350ºC, the briquetting machine was started. During production, the temperature drops to 320-330ºC, and this can be maintained by adding fuel periodically (every 5 minutes) to the stove. Primary air for combustion is taken through the ash-pit door, which is kept open during operation. Secondary air is taken through the fuel doors, which too are kept open partially.

6. Results

6.1. Biomass pre-heating

The heated-die screw-press briquetting machine, with an average production capacity of 90 kg/hr, used a 20-hp motor for driving the screw, and the screw was driven at 385 rpm. Three 2-kW electrical coil heaters were used to heat the die. Rice-husk with a moisture content of about 8 % (wet basis) was used as raw material for briquetting.

Briquetting experiments were carried out during several days, with and without pre-heating the rice-husk. The quality of briquettes produced, with and without pre-heating, was more or less similar, with the outer surface slightly charred.

The major electrical energy consumption in the briquetting process was due to the motor, about 62 % of the total consumption, without pre-heating. Consumption by the electrical coil heaters was nevertheless high, at 68 kWh per tonne of briquettes produced. Energy consumption by the motor driving the screw feeder in the biomass preheater was found to be insignificant, and hence neglected. The results of the experiments are presented in Tables 1 and 2.

Average electrical energy savings at the heater, motor and overall system were 23.5 %, 10.8 %, and 10.2 % respectively. The production capacity was about 88 kg/hr.

6.2. Die-heating stove

Experiments were carried out with the die-heating stove, using rice-husk briquette pieces as fuel. The stove was partially loaded with fuel so that the die was surrounded by fuel. The fuel was ignited from below the grate, with the help of some kindling. After the fire developed well, additional fuel could be added. The die temperature was allowed to reach 350ºC before the machine was started. During steady operation, the die temperature was found to stabilise around 300-320ºC, which was the appropriate range for good briquetting. Fresh fuel (briquette pieces) was added every 5 or 6 minutes, and the ash was scraped through the grate every 15 minutes. The smoke from the

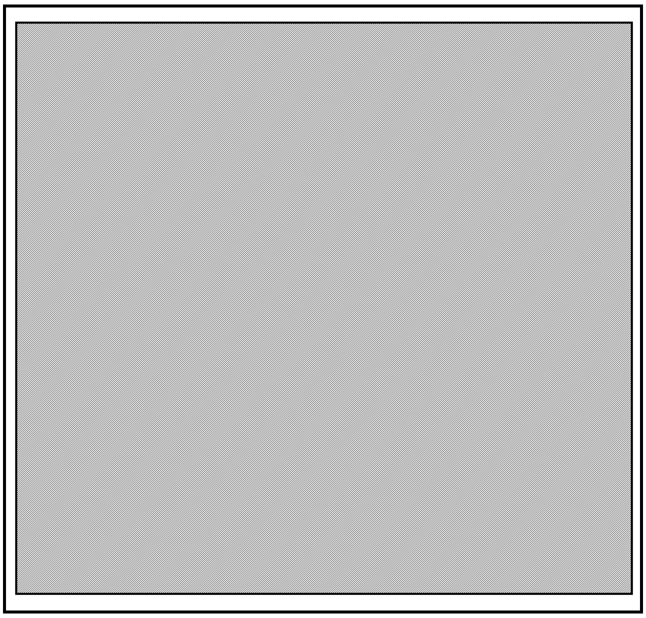

Figure 4. Biomass die-heating stove in operation

stove was carried away by a chimney (Figure 4).

The stove was found to reduce the total electrical energy consumption for briquetting by about 35 %. It could perform continuously over extended periods of time without any problem. The fuel consumption rate of the stove was about 4.5 kg per hour.

7. Conclusions

Experiments were conducted on a heated-die screw-press briquetting machine. The following observations were made:

- Average savings in the electrical energy consumption due to pre-heating were 23.5 % at heater and 10.8 % at motor respectively. The average total energy saving was about 10.2 %.
- The lowest electrical energy consumption for rice-husk was 0.172 and 0.150 kWh/kg of briquettes produced, without and with pre-heating respectively.
- The biomass stove developed for die-heating was found to perform satisfactorily, and requires periodical fuel-loading and ash-scraping. The stove could heat the die to the required temperature range of 300-320ºC for briquetting during continuous operation.
- Average electrical energy saving due to replacement of electrical heaters with the biomass stove for die-heating was estimated to be about 35 % of total electrical energy consumption. ■

Acknowledgements

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References

Aqa, S., 1990. *A Study of Densification of Pre-heated Sawdust,* Master's thesis No. ET-90-4, Asian Institute of Technology, Thailand.

Aqa, S., and Bhattacharya, S.C., 1992. "Densification of preheated sawdust for energy conservation", *Energy,* Vol. 17, No. 6, pp. 575-578.

Grover, P.D., and Mishra, S.K., 1996. *Biomass Briquetting: Technology and Practices,* RWEDP Field Document No. 46, Food and Agriculture Organization of the United Nations, Bangkok, 1996.

Joseph, S., Hislop, D., and Errey, S., 1985. *The Development of an Energy Production System to Briquette Papyrus Through Partial Pyrolytic Conversion,* Biomass Energy Services and Technology, BEST, December.

Joseph, S., and Hislop, D., 1985. "Residue briquetting in developing countries", *Energy From Biomass,* 3, Elsevier, London, pp. 1064-1068.

Mishra, S.K., 1996. "Hardfacing of screw for wear resistance", *Proceedings of the International Workshop on Biomass Briquetting,* New Delhi, India, 3-6 April 1995.

Reed, T.B., Trezek, G., and Diaz, L., 1980. *Biomass Densification Energy Requirements, Thermal Conversion of Solid Wastes and Biomass,* American Chemical Society.