

DEVELOPMENT OF SINGLE PELLETTIZER UNIT FOR MODELLING FLAT DIE PELLETTIZER

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ABSTRACT

Pelletizing is currently one of the most frequently used method for producing agglomerates, using either a ring die or a flat die pelletizer. This process can increase bulk density, reduces storage and transportation costs and makes easy handling of biomass. Raw materials for fuel pellets production can be different types of biomasses from various resources. Also composition and structural properties of these materials are diverse. This has the consequence that different types of biomass require different processing conditions such as press channel length, moisture content, particle size and temperature. Nowadays, the process optimization is mainly based on expensive and time-consuming “trial and error” experiments and personal experience [2]. The aim of this work was modelling the pelletizing behavior of different raw materials with an experimental equipment based on piston press: single pelletizer unit (SPU). Compressibility was determined, and pellets were produced by flat die pelletizer, and results were compared with results of single pelletizer unit. During this modelling the parameters could be changed easily, and the amount of the raw material is low for the experiment. This enables a fast estimation of key process parameters such as optimal press channel length, moisture content, pressure, temperature, particle size and speed of piston.

Keywords: Press channel, flat die pelletizer, hydraulic piston press, single pelletizer.

1. Introduction

Fine disperse materials are present in lot of industry and large part of them have to be briquetted. The agglomerated form has many advantages against bulk form. Lot of agglomeration equipment types are able to produce biomass pellets or other agglomerated forms. The flat die pelletizer is a good example, it has large capacity. This agglomeration process and the behavior of raw material in the hole of flat die could be modelled in an experimental hydraulic piston press. It has the advantage that the processes in flat die pelletizer could be described and modelled, the parameters can be easily modified.

2. Literature overview

The press channel model in experimental piston press has recently been studied by many research groups, such as Nielsen et al. (2009a), and Abedin Zafari et al. (2012).

Nielsen et al. [1] presented tools and methods that separate the pelletizing process into compression, flow and friction components, to measure the importance of raw material properties for the energy requirements of pelletizing, and pellet strength. Experimental materials were sawdust from European beech and Scots pine. Test procedure can be seen in figure 1.

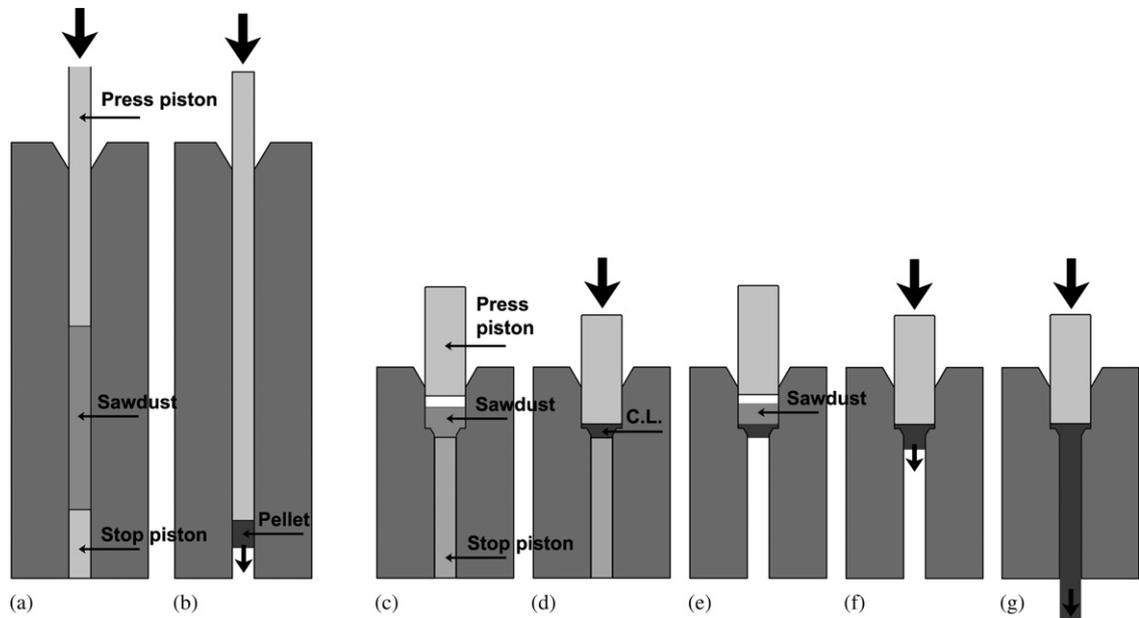


Figure. 1

Illustrations of test procedures. (a – b) The procedure for compression and friction analysis; (c – f) the flow analysis; (g) the continuous pelletizing [1].

Zafari et al. introduced in [3] their research work about the experimental design to evaluate the effect of moisture content, speed of piston, die length, and particle size on pellet density, and obtained maximum density. Experimental material was composted municipal solid waste, press channel had 10 mm diameter, total length of the active part was 100 mm. Statistical analyses confirmed that the moisture content, speed of piston, and particle size significantly affected the pellet density.

3. Equipments

Hydraulic piston press (figure 2.) was designed and produced by the Institute of Raw Material Preparation and Environmental Processing (University of Miskolc). The press is supported by a pump motor unit with pressure limiter and a heatable load cell (20...140°C). The maximal force is 200 kN, and the maximal velocity of the piston is 30 mm/s. The measuring of the piston position is made by incremental method. The data acquiring is made by PC (LabWindows). Hydraulic piston press with a single pelletizer unit were used to produce experimental pellets.



Figure. 2
Hydraulic piston press

Flat die pelletizer (figure. 3) system contains a press, mixing container, conditioning screw and a steam generator (Theobald TJ-Extra II, 19 kg/h steam). Capacity of pelletizer is 50...100 kg/h depending on feed, during our experiment it was 60 kg/h. Diameter of flat die is 200 mm, hole length is 28 mm, and diameter is 8 mm.



Figure. 3
Flat die pelletizer

4. Development of single pelletizer unit

During this work a single pellet unit were used, which was mounted in the hydraulic piston press. Length of active part was 55 mm, the diameter of the hole was 8 mm. A piston (diameter: 8 mm, length: 15 mm limited by a cylinder (height: 26 mm)) can force the raw material to the chamber. Above the piston a force meter was built in (type: Kaliber 8923-1 ton, height 46 mm) to measure the actual force. The designed press channel and piston of single press unit are shown on figure 4.

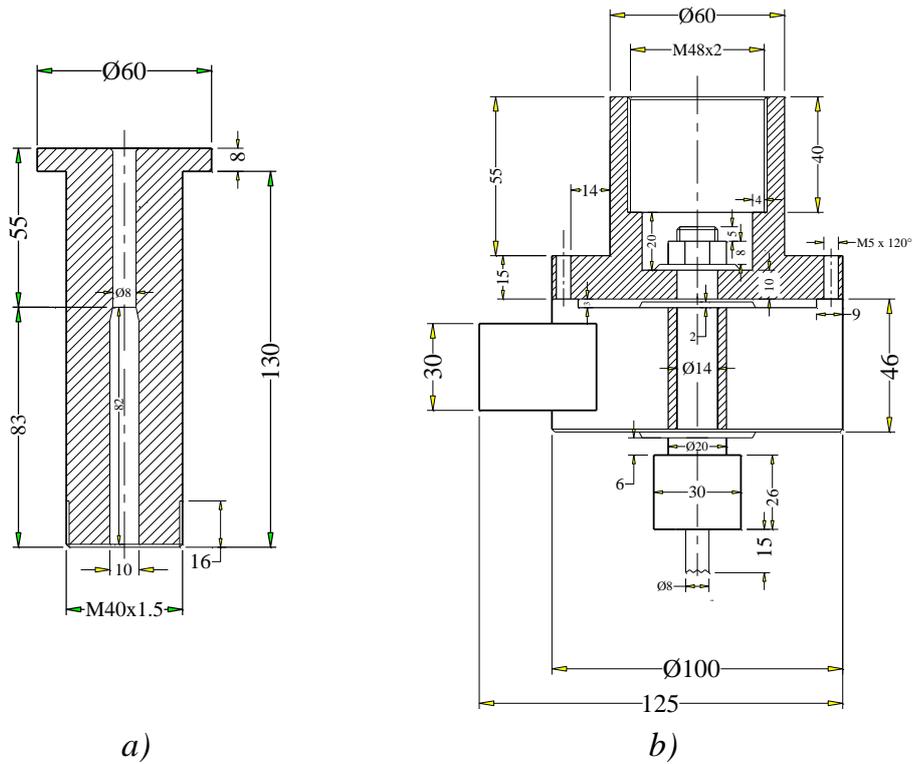


Figure. 4

Design of new single pelletizer unit: press channel (a) and piston (b)

5. Materials and methods

5.1 Sample preparation

Spelt chaff was chosen as raw material for our experiments. It is originated from Szendrő, Hungary (Natur Gold Farms Ltd.). It was dried and then ground using cutting mill (Retsch SM2000) in two steps (screen sizes: 2 mm, 1 mm). Moisture content of ground spelt chaff biomass (<1 mm) was determined as 6.3% and bulk density 224 kg/m³. The moisture content of chaff biomass were then adjusted to 10%, 15%, 20% and 25%.

5.2 Determination of pellet density

The density of each individual pellet was calculated by measuring the length and diameter of the pellet cylinder using an electronic caliper and by measuring the mass using an electronic scale with a precision of 0.01g. To achieve a uniform length, the edges of the pellets were smoothed. Pellet density was calculated by dividing mass of individual pellets by their volume calculated from length and diameter [4].

6. Results and discussion

Compressibility of spelt chaff was determined, and pellets were produced by flat die pelletizer. Afterwards chaff was compressed using a single pelletizer at various conditions based on an experimental design to evaluate the effect of moisture content (X1), particle size of feed (X2), temperature (X3).

6.1. Determination of compressibility

With hydraulic piston press tablets were produced to determine the compressibility of the raw material. 25 mm diameter closed form chamber was used. The feed material was produced from pre agglomeration and grinded spelt chaff biomass with particle size $x < 1$ mm, because tablets were not formed from simple raw material. Table 1 shows the tablet density values which are recorded as an average of three measurements with weight of sample 3 g, moisture content 20%, temperature 100°C.

Table 1
Tablet density values with particle size $x < 1$ mm

Pressure, p (MPa)	Density, ρ (kg/m ³)			
	ρ_1	ρ_2	ρ_3	$\bar{\rho}$
50	992	926	1010	952
100	966	952	956	957
150	948	949	997	964
200	969	977	1002	982
250	1002	989	971	986
300	1023	975	1002	999

Figure 5 show the relationship between pressure and density, described by linear function:

$$\rho = 0.194286 \times p + 939.33.$$

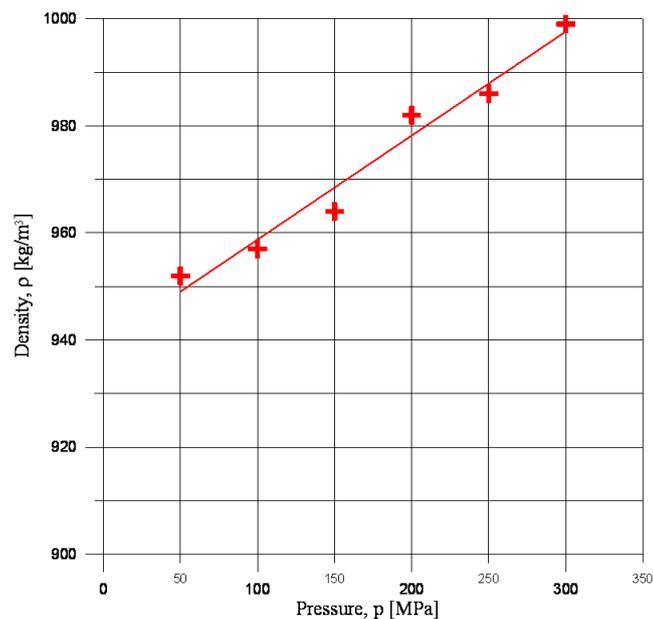


Figure. 5

Pressure-density diagram for biomass (particle size $x < 1$ mm)

6.2. Pellet production by flat die pelletizer

Ground raw material was fed at five times (recirculated) on flat die pelletizer. Figure 6 shows the produced pellets, their moisture content was 16 %. Table 2 shows the measured densities.



Figure. 6
Pellets are produced by flat die pelletizer

Table 2
Measured geometrical parameters and densities of pellets

Pellet	X1 (%)	X2 (mm)	Density of the pellets, ρ (kg/m ³)			
			Diameter (mm)	Length (mm)	Weight (g)	Density (kg/m ³)
1.	16	1	8.3	31	1.67	996
2.	16	1	8.3	33	1.84	1031
3.	16	1	8.4	33	1.81	990
$\bar{\rho}$						1005

6.3. Pellet production by single pelletizer unit

During the process 0.2 g of pre agglomerated and ground spelt chaff biomass was fed into the channel. After that it was pressed and moved downwards 15 mm in the channel by the piston, the piston was lifted. This was repeated until 20 g raw material were fed. The force limit was set to 350 MPa, and speed of piston was 6 mm/s. Figure 7 shows the pellets produced from hydraulic piston press on 100 °C and with 20 % moisture content.



Figure. 7
Pellets produced by single pelletizer unit (hydraulic piston press)

Table 3 shows pellet densities made by single pelletizer unit. Experiment were carried out with pre agglomerated and grinded raw material.

Table 3
Experimental design

Original material	X1 (%)	X2 (mm)	X3 (°C)	Density of the pellets, ρ			
				Diameter (mm)	Length (mm)	Weight (g)	Density (kg/m ³)
Raw material	10	1	100	no pellets were formed			
	15	1	100	8.0	5.0	0.08	318
	15	1	80	no pellets were formed			
	15	1	60	no pellets were formed			
	15	1	40	no pellets were formed			
	20	1	100	8.2	7.0	0.12	341
	25	1	100	8.2	13.0	0.24	349
Pre pellet	10	1	100	8.2	18.0	0.57	599
	15	1	100	8.4	63.0	2.99	856
	15	1	80	8.4	47.0	1.74	668
	15	1	60	8.4	27.0	0.87	582
	15	1	40	no pellets were formed			
	20	1	80	8.4	36.6	1.85	913
	20	1	100	8.4	76.5	5.01	1182
	25	1	100	8.4	29.0	1.34	834

7. Conclusions

This article has presented a model and experimental procedures for pelletizing, where different conditions can be set easily, and the amount of the necessary feed material is low. It is possible to produce pellets with the developed single pelletizer unit.

Examination of compressibility showed that pre agglomeration is necessary for the good quality tablets. The densities of 3 g tablets are in a small range (952, 964, 982, 986, 999 kg/m³). Larger tablets (5 g) had fractures. The reason for that can be the small lignin content. The pressure-density relationship can be described by a linear equation.

The systematic experiments with SPU showed, pellets made from grinded raw material were not strong enough (densities: 341 and 349 kg/m³)

Pellets produced from pre agglomerated and reground feed by SPU had large densities (856, 913 kg/m³). The maximal density was 1182 kg/m³, it was reached with 20 % moisture content on 100 °C. The decreasing of temperature resulted smaller density values both on 20 and 15 % moisture content. On 40 °C it was not possible to produce pellets.

The developed pressure in the flat die pelletizer can be estimated from densities of produced pellets (1005 kg/m³) by the pressure density diagram. It can be assumed that the pressure was over 300 MPa.

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