Experiment study on cold compression of biomass materials

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Abstract. Solar, hydroelectric, wind, biomass are all renewable sources of energy. And biomass energy market has a tremendous development potential. In this paper, some experiments were made by using WDW-100 microcomputer controlled electronic universal testing machine to find a better way to realize cold compression of biomass material. The experimental results show that moisture content, compression speed, particle size and residence time have obvious effect on the molding blocks. Considering all the factors, a better molding block would get with a compression speed of 40mm/min, 16% moisture content and a small particle size.

1. Introduction

Straw cold compression molding was an important technology of developing and utilizing biomass resources. As for the basis of biomass energy utilization, straw cold compression molding has become a hot topic in the field of renewable energy[1]. Recently, many universities have been done lots of studies on biomass briquetting equipment, such as Shandong University, Henan Agricultural University, Jilin University and so on[2]. This paper mainly concentrates on the forming mechanism and influence factors in the process of cold compression molding. These main influencing factors of the experiment include material type, compression speed, residence time, compression ratio, compressive force and so on.

2. Method and process

A WDW-100 microcomputer controlled electronic universal testing machine was applied in the experiment. It consists of three systems which are loading system, control system and measure system. And the testing machine has a speed range of 0.05-500mm/min, and the range of force measurement is 0-50KN. The testing machine can be operated either by the manipulator and the switch or through the upper computer.

The experiment mainly involves four kinds of materials: sawdust, corn cob, peanut shell and leaves. Since there are several influence factors, thus the control variable method is adopted. And the mainly factors we control are: moisture content [3], compression speed, particle size and residence time[4].

The following principle was adopted to cope with the data:

Pressure: $$P = \frac{F}{\frac{1}{4}\pi d^2} \tag{1}$$

Initial density: $$\rho_0 = \frac{m}{\frac{1}{4}\pi d^2 L} \tag{2}$$

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Compression density: $$\rho = \frac{m}{\frac{1}{4}\pi d^2 (L-s)} \tag{3}$$

Energy consumption[5]: $$E = \int \frac{F}{m} dx = \frac{1}{4}\pi d^2 \int \frac{P}{m} dx \tag{4}$$

In the type, F is the pressure which the biomass material is loaded; m is the weight of the biomass material; L is initial height of the biomass material; D stands for the diameter of the sleeves; S stands for the displacement of the rod.

The detail experimental method which we apply is as follows:

1).Each kind of material was wetted to have 8, 14, 16 and 18% moistures content.

2).Configure five kinds of compression speed (10mm/min, 20 mm/min, 40 mm/min, 60 mm/min, and 80 mm/min) for each material.

3).Set the residence time to three levels: 1min, 10min and 15min.

4).Take experiment about different moisture content under the condition of the same material and the same compression speed.

5).Take experiment about different compression speed under the condition of the same material and the same moisture content.

6).Take experiment about different materials under the condition of the same compression speed and the same moisture content.

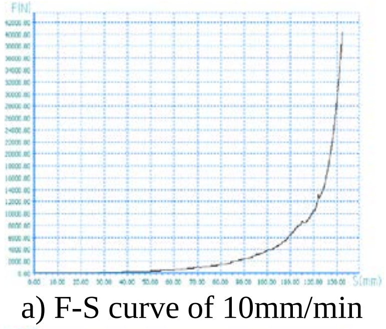
7).Take experiment about different residence time in the same compression condition.

3. Analyses experimental results

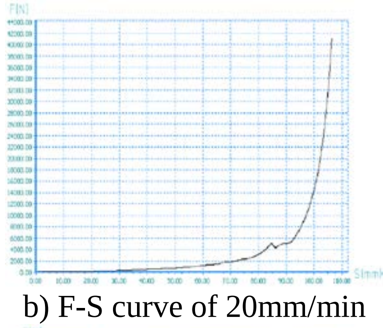
3.1 Different compression speed

In this process, the compression curves of different materials in the speed of 10 mm/min, 20 mm/min, 40 mm/min, 60 mm/min and 80mm/min at 16$^{\circ}C$ and 14% moistures content were got, as shown in Fig.4-7. Since the curves are related to F (The pressure the biomass material is loaded) and S (Displacement of the rod), we call them F-S curves. And detail explanation was given after the curves.

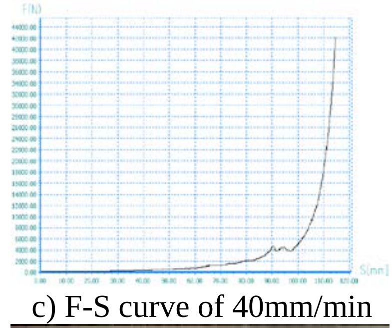
a) Sawdust



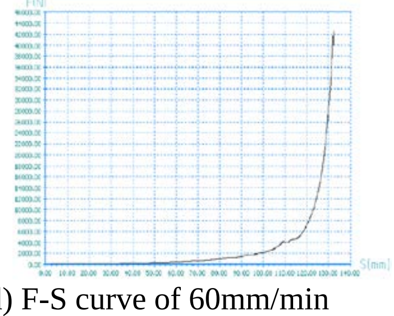
a) F-S curve of 10mm/min



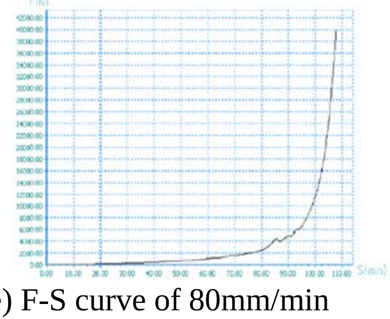
b) F-S curve of 20mm/min



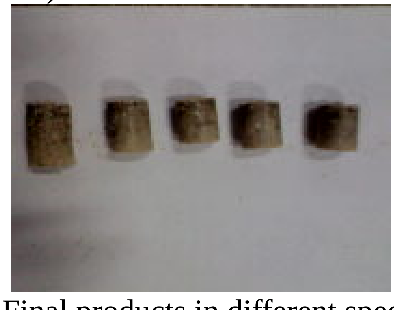
c) F-S curve of 40mm/min



d) F-S curve of 60mm/min



e) F-S curve of 80mm/min



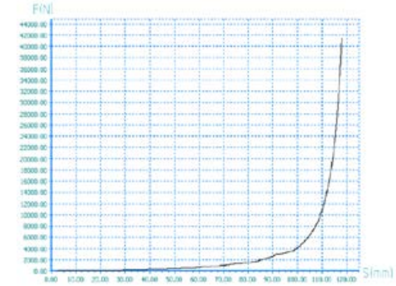
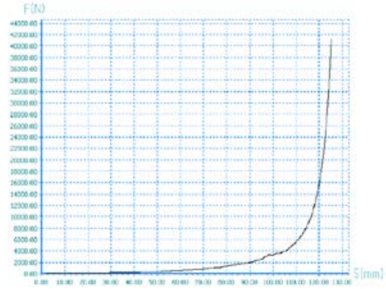
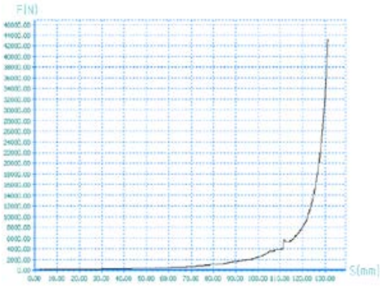
f) Final products in different speed

Fig.4. F-S curves and compression models of sawdust

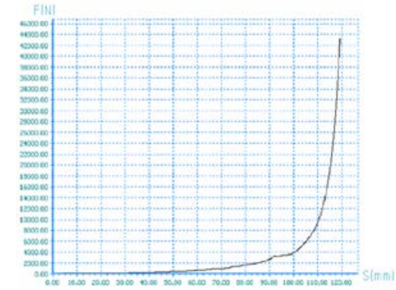
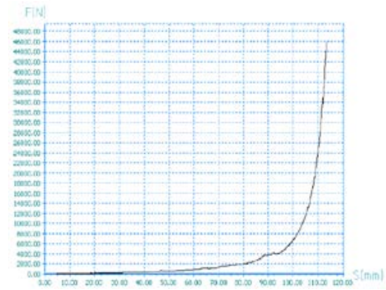
It can be concluded from these curves that different compression speed has a similar effect on the molding of the sawdust. However, it still meets the following rules: the larger the compression speed is the less the curve fluctuates at the very beginning. And when the pressure was reached to

32MPa, the curve would rise suddenly. Also, we can see that the curve fluctuates much in the late stage of molding process. As far as we can see, the reason it occurs is that the accuracy of the mold equipment is not enough. Seen from Fig.4-f, the final product has a best quality in the speed of 10mm/min while the final products have a worst quality in the speed of 80mm/min. But there was a little difference between two products. Thus, the speed of 40mm/min was mainly applied in the experiment.

b) Corn cob

a) F-S curve of 10mm/min b) F-S curve of 20mm/min c) F-S curve of 40mm/min

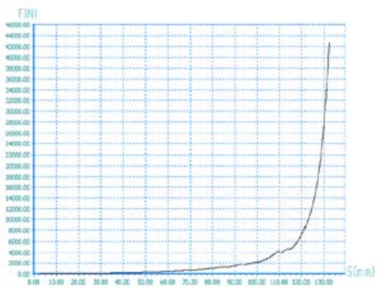
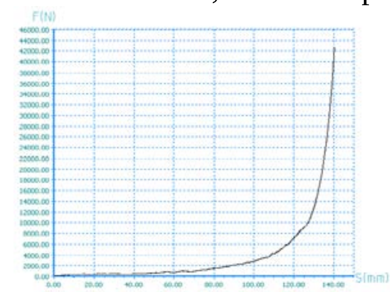
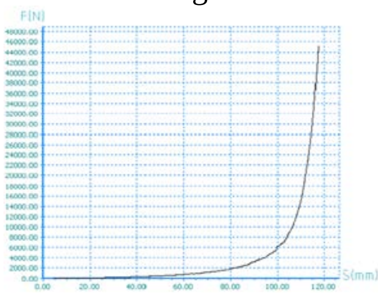

e) F-S curve of 80mm/min d) F-S curve of 60mm/min f) Final products in different speed

Fig.5. F-S curves and compression models of corn cob

Because the difference of particle size between sawdust and corn cob, the curves in Fig.5 was a little different. But the total trend was the same. And when the pressure was reached to 25MPa, the curve would rise suddenly. Also, we can see that the curve still fluctuates much in the late stage of molding process (at the point of 100mm). Thus, this confirms that the accuracy of the equipment causes this consequence [6].

c) Peanut shell

Take the former two experiments into consideration, only three speeds (20 mm/min, 40 mm/min and 60mm/min) were applied in this experiment. Also, the F-S curves and the final products were got. These curves were really similar to the former. But the quality of the final models was worse than sawdust and corn cob. Maybe this was caused by the shape of peanut shell since peanut shell has a sheet structure. In order to find this influence, another experiment was following took.

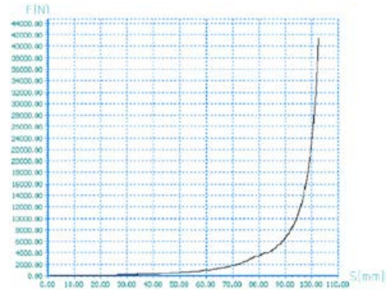




a) F-S curve of 10mm/min b) F-S curve of 20mm/min c) F-S curve of 60mm/min

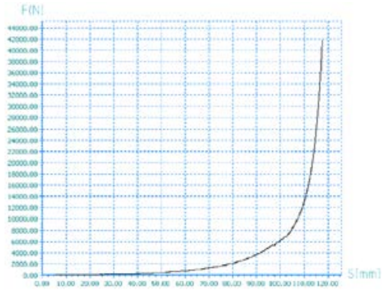
d) Final products in different speed

Fig.6. F-S curves and compression products of peanut shell

d) Leaves



a) F-S curve of 20mm/min



b) F-S curve of 40mm/min

c) Final products in different speed

Fig.7. F-S curves and compression products of leaves

The F-S curves were also similar to the former ones. But as far as we can see from Fig.7-c, the quality of leaves products is the worst in four experiments, which verifies the former conjecture about sheet structure that the material with sheet structure was difficult to mold.

3.2 Different moisture content

Given that the sawdust can be molded better this experiment was made only towards sawdust. And the final result told that the curves were substantially the same under different moisture conditions. In the meanwhile, several differences can be seen from the process: the moisture content has an obvious effect on the final products (Fig.8). The higher the moisture content was, the more the material swells. And good moisture content was the most important factor in the reality.

Fig.8 Products with moisture content of 14%, 16% and 18%

4. Conclusion

In this paper, some compression molding experiment towards different materials were made by WDW-100 machine. Results are shown that the F-S curves in the process of compression molding towards the four biomass materials were in the same trend. And the compression speed has little effect on the final product. Moisture content has great influence on the expansionary of the molding blocks, where the higher the moisture content was, the more the material swells.

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