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Study on Different Ultrasound Assisted Modes in Biomass Compression

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ABSTRACT. *In view of the lack of compactness in traditional biomass compression processing technology, the effects of different ultrasound-assisted modes on the compaction of biomass are studied. Using biomass briquettes volume as an indicator of compression compactness, Compressed biomass experiments in three modes without ultrasound assisted, single ultrasound assisted and double ultrasound assisted under the same experimental conditions, the experiment results show that under the double ultrasonic assisted compression biomass mode, the compaction of compaction can be greatly improved and the compaction volume can be reduced. So this study has a good reference for reducing the cost of biomass briquettes in transportation and storage and improving the calorific value of biomass briquettes.*

Keywords: *Ultrasound assisted compression; Compactness; processing mode; Biomass.*

1. Introduction

With the advancement of science and technology and the development of society, human beings are increasingly demanding energy. Environmental and energy issues have become a serious problem in the development of countries around the world[1].Relevant researchers are paying more and more attention to biomass energy processed from agricultural and forestry waste[2-3].

According to statistics, the total amount of coal energy in the world is only about 200 years old, and fossil energy can only last until the middle of the 21st century [4].Therefore, green biomass energy is recognized as the third largest renewable energy in the world. It has good environmental friendliness, can effectively alleviate the global energy shortage and has good industrialization prospects and great development potential [5].China has clearly proposed to vigorously develop sustainable use of biomass energy from 2005 to 2020. During this period, green clean energy will be guaranteed to account for more than 15% of national energy demand, and carbon emissions will be reduced by 40-45%[6-7].Biomass energy is the first choice for the World Energy Commission and the United Nations Development Programme to develop new energy sources. The Food and Agriculture Organization of the United Nations uses biomass energy as an important measure to reduce global carbon emissions at the same time [8].Therefore, solving the energy crisis and realizing the sustainable development of the ecological environment are issues of common concern in all countries of the world [9].

At present, biomass energy has direct combustion, compression and compact molding into energy blocks, biochemical conversion technology and thermochemical conversion technology. But relatively speaking, the cost is less for compression compaction into energy blocks. And compared to other methods, biomass compact molding requires only mechanical compression, no complicated thermal physics, and thermochemical treatment, simple process and low cost. It is one of the effective ways to develop and utilize biomass energy.

At present, limiting the widespread use of biomass energy, on the one hand, is the low density of biomass energy materials, about (40-250kg/m3), which greatly increases transportation and storage costs. On the other hand, the reasons are compression processing methods and process technology limitations[12].If the improved biomass compression processing method and process can significantly increase the density of raw materials to a bulk density of 600-800 kg/m3, which is easier to process, transport, store and use biomass energy material blocks[13-14].

At present, biomass compaction and compact molding is mainly carried out by means of a conventional molding apparatus, and the pulverized biomass straw is compressed into a rod shape or a block shape by a compression molding apparatus [15-16].At present, traditional biomass molding equipment includes ring mode, flat mode, screw extrusion, piston punch molding machine, pressure roller molding machine, etc. However, these traditional biomass molding machines have the disadvantages of compressing biomass, large density of compacted block, and excessive volume, which results in high production cost of biomass energy fuel and is difficult to be widely applied [19].

Therefore, in view of the above problems, the effects of different ultrasound-assisted modes on the compaction of biomass compression are studied. This research method not only has the advantages of not requiring high-temperature steam treatment or adding additional binder to the biomass, but also only needs to work under normal temperature conditions, which using pneumatic pressure and high-frequency ultrasonic vibrator to pulverize the biomass straw. Further compression into blocks to increase their compactness.

2. Design of experimental platform for compressing biomass with different ultrasound-assisted modes

2.1 Experimental platform design and introduction

The ultrasonic-assisted compression biomass experimental platform is shown in Figure 1, including ultrasonic drive power supply, drive system, compression mold, ultrasonic vibrator No. 1 and ultrasonic vibrator No. 2 in the paper. The performance parameters of the ultrasonic drive power supply are as follows: (1) Input voltage AC220V, output power is adjustable from 200-500W, output frequency is adjustable from 15-35KHz. (2) Drive Simultaneously two ultrasonic vibrators with a resonant frequency in the range of 15-35 KHz. (3) It has automatic frequency tracking function. The drive system includes cylinder (100mm bore, 400mm stroke), pneumatic circuit (air source, pneumatic triplex, directional control valve, throttle valve).At the same time, pneumatic triplex consists of air filter, pressure reducing valve and oil mister. The No. 1 ultrasonic vibrator is connected to the cylinder piston rod and moves up and down linearly with the cylinder. The No. 2 ultrasonic vibrator is fixed on the table below the compression mold. No. 1 and No. 2 have similar performance parameters of the ultrasonic vibrator to improve the mechanical energy conversion of the ultrasonic driving power source into the ultrasonic vibrator.

Fig. 1 Different ultrasound-assisted mode compression biomass experimental platform

2.2 Working principle of experiment platform

The pulverized biomass straw was loaded into a compression mold, and then the compressed biomass experiment was performed under three modes: no ultrasound assisted, single ultrasonic assisted and double ultrasonic assisted before starting the different ultrasonic assisted mode compression biomass experiments. The single ultrasonic assist mode compresses the cylinder together with the No. 1 ultrasonic vibrator; The dual ultrasonic assist mode compresses the cylinder and the No. 1 and No. 2 ultrasonic vibrators in parallel. Finally, the biomass is compressed into a block, and the compaction of the compact in different compression modes is studied. at last. The output pressure of the cylinder is adjusted by the pressure reducing valve in the pneumatic triplex, and the adjustment range is 0-0.55MPa.The up-and-down linear motion of the No. 1 ultrasonic vibrator is realized by the directional control valve switching between the rod chamber and the rod-free chamber gas. The movement speed is adjusted by the throttle valve mounted on the cylinder. The compression mold is closed-formed and consists of two halves which is easy to mold and has good adaptability to biomass materials. Figure 2 shows the working principle of the compressed biomass experimental platform in different ultrasound-assisted modes.

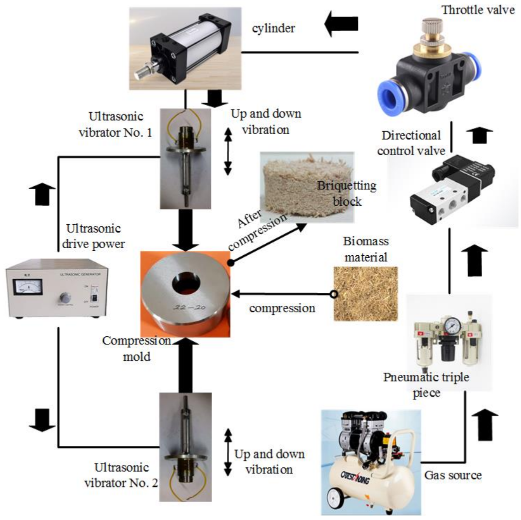


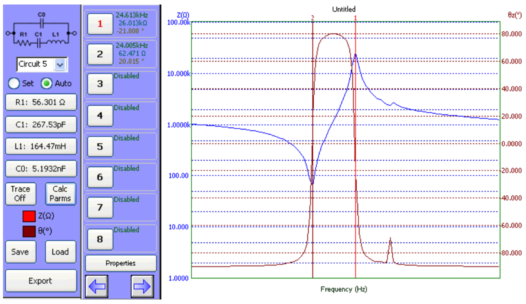
Fig 2 The working principle of the compressed biomass experimental platform in different ultrasound-assisted modes.

2.3 Ultrasonic oscillator introduction

Ultrasonic vibrators are part of compressed biomass experiments, and their performance parameters will affect the quality of biomass compression. The ultrasonic oscillator performance parameters include the series resonant frequency Fs, the parallel resonant frequency Fp and the equivalent impedance R.its equivalent impedance is the smallest, the ultrasonic drive power source has the highest energy conversion efficiency, and the processing quality is the best when the ultrasonic oscillator operates at the resonant frequency. Therefore, the resonant frequencies are inconsistent, which will have a greater impact on the bio-compression effect when two ultrasonic vibrators with large difference in performance parameters are compressed in parallel. Therefore, two ultrasonic vibrators with the same or similar performance parameters are important guarantees for the success of single-power-driven dual-ultrasonic vibrator-assisted composite compression biomass experiments. Figure 1 shows the No. 1 ultrasonic vibrator and the No. 2 ultrasonic vibrator.

Fig.3 Ultrasonic vibrator physical map

Ultrasonic vibrator No. 1 is tested by PV70A impedance analyzer (Fig. 3 left).Because the impedance curve and the admittance circle curve are closely related to the performance parameters of the ultrasonic oscillator. Therefore, if the impedance curve exhibits a valley and a peak, the phase angle exhibits a "several" shape, and the admittance circle curve is a complete circle, indicating that the ultrasonic oscillator has a low dynamic resistance R, a high quality factor Qm, a good structural state and conversion to mechanical energy is highly efficient. As can be seen from Figure 4, the impedance curve of the No. 1 ultrasonic oscillator exhibits a valley and a peak. The phase angle is in a "several" shape, and the admittance curve is a complete circle, indicating that the overall performance is good. Figure 4 is an impedance analysis diagram of No. 1 ultrasonic vibrator, and its performance parameters are shown in Table 1.

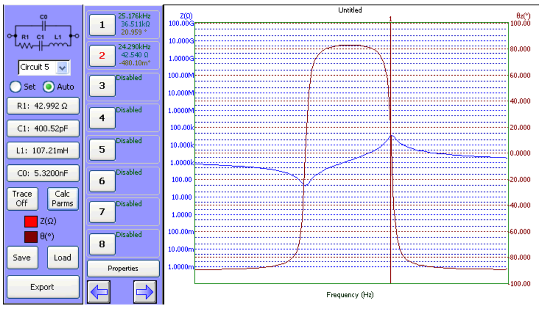


R1: 56.301 Ω
C1: 267.53pF
L1: 164.47mH
C0: 5.1932nF

1 24.613kHz 26.013kΩ -21.808 °
2 24.005kHz 62.471 Ω 20.815 °
3 Disabled
4 Disabled
5 Disabled
6 Disabled
7 Disabled
8 Disabled

Fig. 4 No. 1 ultrasonic oscillator impedance analysis diagram

The impedance curve of the No. 2 ultrasonic vibrator (Fig. 3 right) tested by the impedance analyzer PV70A presents a trough and a peak. The phase angle shows a "several" shape, and the admittance circle curve is a complete circle, indicating the overall ultrasonic vibrator No. 2 which shows the overall performance of the No. 2 ultrasonic vibrator is good. Figure 5 is an impedance analysis diagram of No. 2 ultrasonic vibrator, and its performance parameters are shown in Table 1.



Circuit 5

○ Set ● Auto

R1: 42.992 Ω

C1: 400.52pF

L1: 107.21mH

C0: 5.3200nF

1: 25.176kHz 36.511kΩ 20.959 °

2: 24.290kHz 42.540 Ω -480.10m°

3: Disabled

4: Disabled

5: Disabled

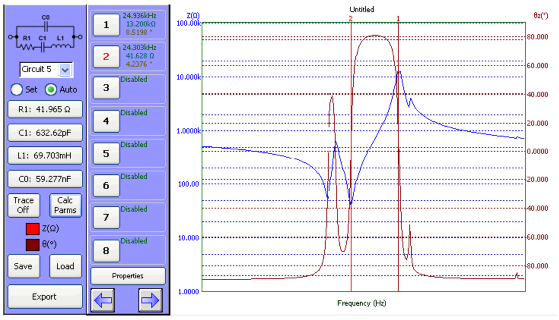
6: Disabled

7: Disabled

8: Disabled

Fig. 5 No. 2 ultrasonic oscillator impedance analysis diagram

The test result of the impedance analyzer PV70A is shown in Fig. 6, in the condition that the No. 1 ultrasonic vibrator is connected in parallel with the No. 2 ultrasonic vibrator.The impedance curve shows almost a trough and a peak,and the phase angle also shows a "several" shape. The admittance circle curve is a complete circle, indicating that the overall performance of the ultrasonic transducers of No.1 and No.2 is good.



Circuit 5

○ Set ● Auto

R1: 41.965 Ω

C1: 632.62pF

L1: 69.703mH

C0: 59.277nF

1: 24.936kHz 13.200kΩ 8.5198 °

2: 24.303kHz 41.628 Ω 4.2376 °

3: Disabled

4: Disabled

5: Disabled

6: Disabled

7: Disabled

8: Disabled

Fig. 6 Impedance analysis diagram of No. 1 ultrasonic oscillator in parallel with No. 2 ultrasonic oscillator

The No.1 ultrasonic vibrator, the No. 2 ultrasonic vibrator, and the No. 1 and No. 2 in parallel ultrasonic vibrators are individually tested by the impedance analyzer PV70A.

Table 1 Ultrasonic oscillator performance parameters

Ultrasonic oscillator	Fs(KHz)	Fp(KHz)	R(Ω)
1	24.005	24.613	56.301
2	24.290	25.176	42.922
Parallel connection 1, 2	24.303	24.936	41.965

As can be seen from Table 1,the impedance parameters of the No. 1 ultrasonic vibrator, the No. 2 ultrasonic vibrator, and the No. 1 and No. 2 ultrasonic vibrators in parallel are tested by the impedance analyzer PV70A which shows that the resulting performance parameters are close.It shows that the parallel performance parameters of No.1 and No.2 vibrators meet the experimental requirements. After parallel connection, the overall performance is good, and the electrical energy is converted into mechanical energy with high efficiency and low energy loss.

3. Experiment and discussion on compression of biomass compressed biomass in different ultrasound-assisted modes

3.1 Compressed biomass test process design

The experimental process of compressing biomass in different ultrasound-assisted mode is shown in Figure 8. First, the waste biomass straw is collected, including wheat straw, sorghum stalk, cotton stalk and straw, and then chopped into a length of about 50mm by a mower. The scraps are finely pulverized by a hammer mill and then finely pulverized by MS350A hygrometer and 15mm standard sieve to make the humidity and particle size meet the test requirements.The material was strictly weighed 2.0g with JJ300A electronic balance (accurate to 0.01g), then the weighed material was loaded into the compression mold of the experimental platform for related compression molding experiments, and finally the spiral micrometer was used (accurately 0.001 mm). The thickness h of the compact (known to compress the cavity diameter D of the mold) was measured, and the volume of each compact was determined.

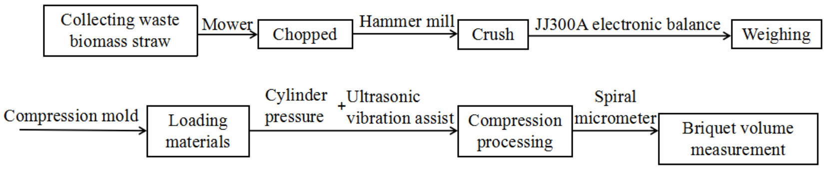


Fig. 8 Biomass compression process flow chart

3.2 Test process

This experiment consists of three independent experiments: no ultrasound-assisted compression, single-ultrasonic oscillator-assisted composite compression (that is, only the ultrasonic power source drives the No. 1 ultrasonic vibrator compression) and dual-ultrasonic oscillator-assisted composite compression (that is, two parallel connections are simultaneously driven by the ultrasonic power supply). The performance parameters are similar to the ultrasonic vibrator compression). Then, the volume of the three experimental compacts was compared to determine the compactness of the biomass compact.

The experimental conditions are as follows: When the ultrasonic power supply output V0=100V, the pre-pressure is 0.3MPa, and the material remaining on the inner surface of the compression mold is not considered in the compression process. The original mass of each sample is m=2.0g, and the compression mold diameter D=20mm. After compressing for a certain period of time (divided into three time boundaries of 20s, 70s, and 120s), the thickness h of the compressed compact is measured. With V = π d2h/4, the volume of each compact can be obtained.

3.3 Comparison and discussion of experimental results

Five samples were taken from each set of experiments, and the average fitting value was obtained, and the relationship between the volume of the compact and the compression time after the graduated material was compressed. Figure 9 below shows the plot of the volume change of the compact obtained by compressing the biomass in different ultrasound-assisted modes.

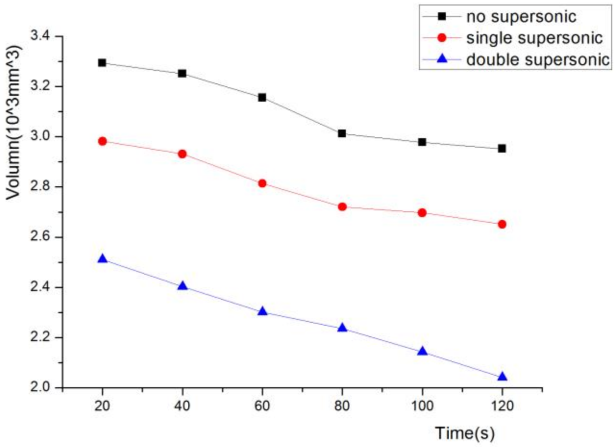
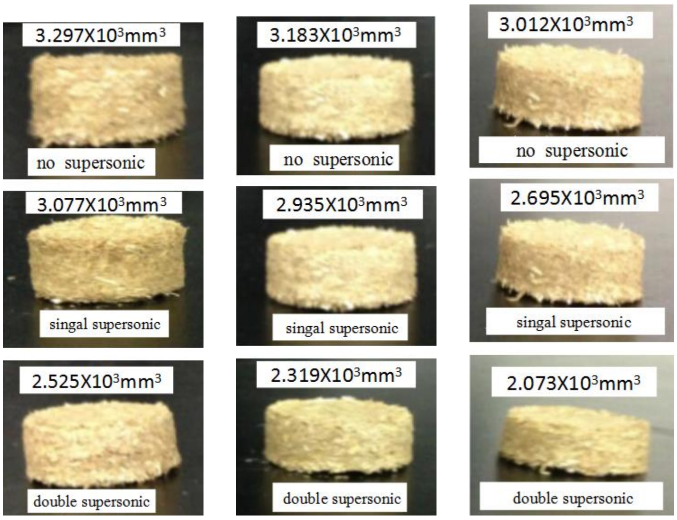


Fig. 9 Curve of biomass compression volume with time in different ultrasound-assisted modes

It can be seen from figure 9 that the same compression time, the volume of the ultrasonic assisted composite compression compact is smaller than that without the ultrasonic assisted compression, and the volume of the compact obtained by the double ultrasonic oscillator assisted composite compression is significantly smaller than that of the single ultrasonic oscillator assisted composite compression.

As shown in Figures 10(a), (b) and (c), there is no ultrasonic assisted compression, single ultrasonic oscillator-assisted composite compression, and dual-ultrasonic oscillator-assisted composite compression in parallel with ultrasonic transducers No.1 and No.2, and different compression times. Volumetric physical map of biomass compacts.



(a) Compression time 20s (b) Compression time 70s (c) Compression time 120s

To simplify the description of the experimental process, let A= no ultrasound-assisted compression, B= single-ultrasonic oscillator-assisted compression, and C=double-ultrasonic oscillator-assisted composite compression. It can be seen from figure 10 that when the compression time is 20s, as shown in figure 10(a), B is compared with A, and the compact density is increased by 6.67%; C is compared with B and A, respectively, and the compact density is increased by 17.93% and 23.41%. As shown in figure 10(b), B is compared with A to increase the compact density by 7.79%; C is compared with B and A, respectively, and the compact density is increased by 20.98% and 27.14% respectively when the compression time is 70s.As shown in figure 10(c), B is compared with A to increase the compact density by 10.52%; C is compared with B and A, respectively, and the compact density is increased by 23.08% and 31.18% respectively when the compression time is 120s.

The possible reasons for the experimental results are as follows: First, under the high frequency vibration of the double ultrasonic vibrator, the biomass particles continue to move, begin to recombine, the relative positional relationship changes, and the particles continuously fill the gap between the particles, so that the compact

The density is significantly reduced; Second, under the action of cylinder pressure and vibration of the double ultrasonic vibrator, the size of the large biomass particles changes, the large biomass particles are fragmented, and the interlacing and fitting occur, and the density of the compact is also significantly reduced; Thirdly, under the action of cylinder pressure and vibration of the double ultrasonic vibrator, the particles undergo residual stress during the crushing process, and the particles are adsorbed to each other to reduce the density of the compact. Fourth, under the action of cylinder pressure and vibration of the double ultrasonic vibrator, high frequency friction between the biomass particles generates heat, and the temperature gradually increases, so that some of the biomass particles soften or even liquefy, acting as a binder between the particles, so that The bonding between the particles is more compact, resulting in a significant reduction in the compact density.

4. Conclusion

This paper compares the results of compression of biomass in different ultrasound-assisted modes. The double ultrasonic transducer assisted compression mode has the best processing effect, and the biomass compact has the highest compactness. It can be seen that the addition of double-high frequency ultrasonic vibrator-assisted compression processing on the basis of traditional biomass compression processing can not only solve the problem of high transportation and storage cost due to the low density of compacted block during the compression molding stage of biomass energy manufacturing. At the same time, it can effectively improve the combustion calorific value of biomass briquette per unit volume, the economical and practical use of biomass energy, and is of great significance to promote the development of biomass compression technology and the vigorous development of biomass energy manufacturing

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