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STUDY ON THE OPTIMAL ULTRASONIC EMULSIFICATION SYSTEM OF BIO-DIESEL FUEL BASED ON DDS

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ABSTRACT

This paper applies the direct digital frequency synthesis technology (DDS) to build a controllable variable frequency and waveforms of the bio-diesel fuel phacoemulsification system. The optimal operating parameters of phacoemulsification system are studied by orthogonal experiment. In the experiment, the ultrasonic frequency, waveform, power and process time are changed to study the stability of emulsified bio-diesel fuel. According to the results: when the experimental conditions are amount of emulsifier(Span80，Tween80，Methanol) 3%, bio-oil 20% and 0# diesel 80%, the treating time has the most significant in fluency on the stability of the phacoemulsification bio-diesel fuel, power and frequency are less important and waveform is the least. The optimal operating parameter is power of 30W, frequency of 25 KHz, process time of 8min and waveform of square wave pulse. The emulsification stability of the bio-diesel fuel insurance under these conditions is the best; the stable time of bio-diesel fuel reaches to 2256 hours under room temperature.

Keywords: *DDS; Optimal Ultrasonic Operating Parameters; Emulsifying Systems;*

1. INTRODUCTION

Ultrasound is actually a kind of wave, and therefore can be used as a carrier to load and detect information. However, it is also a form of energy that accelerates a chemical reaction or triggers a new reaction channel [1]-[2]. Bio-diesel fuel uses ultrasound energy to complete the "biomass + diesel oil" emulsion preparation process. Compared with other emulsifying technologies, ultrasonic emulsification can make the droplets disperse more thinly and more narrowly, achieving higher efficiency, better dispersion, and increased emulsion stability.

At present, most of the research on the ultrasonic emulsification of bio-diesel focuses on the emulsifier ratio. The ultrasound technology is only regarded as an auxiliary means to improve the synthesis efficiency, but rarely considering ultrasound parameters. In accordance with the main influencing factors of ultrasonic emulsification, this study used the direct digital synthesis technology (DDS) to design the optimal ultrasonic emulsification system to allow the free adjustment of operating parameters, such as ultrasonic frequency, incentive waveform, and power. Based on these, a study was conducted to determine the optimal operating parameters for the ultrasonic emulsification of the bio-diesel fuel [3]. In the Orthogonal experiment, to change the ultrasonic frequency, waveform, power and process time to study on the stability of emulsified bio-diesel fuel of various ultrasound factors influence and obtain the optimal ultrasonic emulsification system. This report aims to lay the foundation for further popularization and application of ultrasonically emulsified bio-diesel fuel technology.

Section 2 presents the DDS technology in this paper, in section 3, we introduce the optimal ultrasonic emulsification system, experimental verification in and resultes analysis in section 4 and section 5; section 6 gives a conclusion to the whole paper.

2. DDS

Direct Digital Synthesizer (namely DDS) is a technology which generates the adjustable frequency and phase relative to a reference frequency according to the input digital quantity, with several advantages, such as high speed, high precision, constant temperature output, agile frequency and fast reaction etc. By the project of single-chip microcomputer control of DDS together with the impedance matching, we can realize the strict requirements in which ultrasonic generator tracks with high speed, high resolution and low energy consumption

2.1 The Principle of DDS

The working principle of DDS is to produce sine wave in which the frequency and phase are controllable in the way of NC oscillator. Circuit generally includes reference clock, frequency accumulator, phase accumulator, amplitude/phase conversion circuit, D/A converter and low pass filter (LPF). The principle of DDS block diagram is shown in figure 1:

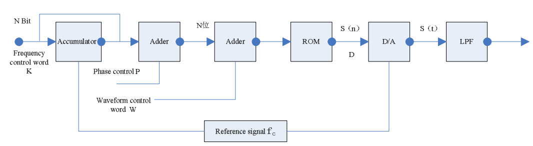

Figure1.The Principle Of DDS

The K is frequency control word, P is phase control word, W is waveform control word, fc means reference clock frequency, N means the word length of phase I accumulator , D means ROM data and D/A converter word length. Phase accumulator in clock under the control of the fc to step K for accumulation, output N bit binary and phase control word P, waveform control word W after adding as waveform ROM address, the waveform ROM for addressing, waveform ROM output D A amplitude code S (N) by D/A converter into staircase S (t), and by the low pass filter after smooth can get synthetic signal waveform. Synthetic signal waveform shape completely in the ROM to form deposited amplitude code, so use DDS can generate arbitrary waveform; Additional output frequency f0 = fcK / 2 N, when K = 1, DDS output minimum frequency for fc / 2 N, DDS and the maximum output frequency by Nyquist sampling theorem decision, namely fc / 2, therefore, as long as N is big enough, DDS can get very fine frequency interval [3].

3. THE OPTIMAL ULTRASONIC EMULSIFICATION SYSTEM

3.1 The System Structure

The system uses the ST89C52 single chip microcomputer as control core, through the serial write control word way to control chip AD9850, coupled with the keyboard and 1602 liquid crystal display part of the peripheral circuit, constitute the whole system circuit [3]-[4], main program control the entire system, including the initialization of control system, display, operation, keyboard scanning, frequency control.

The optimal ultrasonic emulsification system is shown in Figure 2.

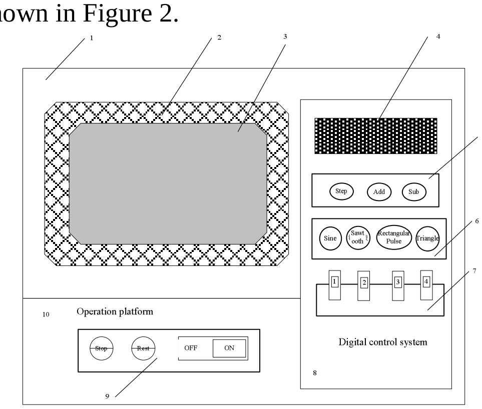

Figure2. The System Structure

(1, Tank; 2, ultrasonic transducer; 3, emulsified liquid; 4, LCD screen; 5, frequency control system; 6, waveform control system; 7, powers choose gear; 8, digital control system; 9, operation platform).

The optimal ultrasonic emulsification system diagram is shown in Figure3.

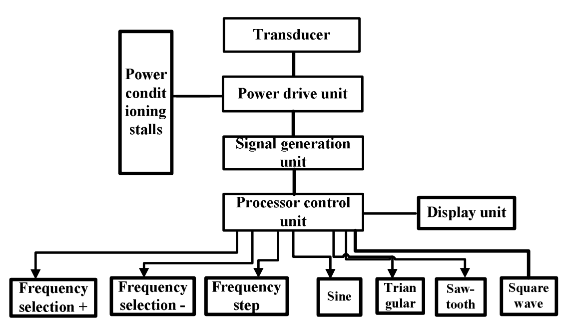

Figure3. System Diagram

3.2 The System Features

The features of the optimal ultrasonic emulsification system:

1) The ultrasonic generator frequency is variable. The frequency of the ultrasonic generator ranges from 20 KHz to 200 KHz. It has three parameter

adjustment buttons: step, frequency plus buttons, and frequency cut buttons. The incentive frequency can be adjusted according to the experimental requirements.

2) The ultrasonic generator waveform is controllable. In order to meet the requirements of various tests and different experiment technologies, the generator is able to generate sine waves, saw-tooth waves, triangular waves, and square pulse wave.

3) The power of the ultrasonic generator can be adjusted. The power adjustment of the ultrasonic generator ranges from 40 W to 200 W.

4) The output from the ultrasonic generator is evenly distributed. Ultrasonic transducers were put around the groove in order to avoid the problem of the uneven distribution of energy of the probe-type ultrasonic transducer.

4. THE OPTIMAL ULTRASONIC EMULSIFICATION EXPERIMENTAL

4.1 Raw Materials and Reagents

The experimental materials included two kinds of straw biomass, soybean straw and corn straw, and two kinds of hard hybrid biomass, birch trees and oak wood.

The main components of the emulsifier included Span80, Tween80, and Methanol. And emulsifying agent configuration experiment was made by HLB = 5[4]-[5].

4.2 BIO-OIL Preparation Process

First, the pre-processed biomass (size 2 to 3 mm) was poured into the heated hot-tip, low energy consumption biomass fast pyrolysis plant that was designed by the present research group. Its biomass processing capacity is 300 kg/h; the average yield of bio-oil can reach 65%; the average calorific value of bio-oil is 21.5MJ/kg; and the production cost control is less than 1500 Yuan/ton.

4.3 BIO-DIESEL Fuel PrepAred by the optimal Ultrasonic EmulSification system

4.3.1 Test method

According to the preliminary experimental results, the experimental conditions were identified as HLB = 5, amount of emulsifier 3%, bio-oil 20%, 0# diesel 80%, and an emulsion temperature of room temperature. The orthogonal design was used to complete the study of the influence of ultrasonic factors on the stability of bio-diesel fuel. A 40 mL emulsion was confected according to the above conditions, and the emulsion was put into the optimal ultrasonic emulsification system.

The ultrasonic emulsification experiments were carried out as follows: the emulsified bio-diesel fuel was prepared after aging at room temperature for 30 min. A small amount was diluted 50 times and then examined with 752-UV-vis spectrophotometer at 500nm measure absorbance values for 0 minutes and 20 minutes, and the stability of the emulsification was computed according to the following formula [6].

$$ESI1 = \frac{A_0 \times \Delta t}{\Delta A} \qquad (1)$$

Where A_0 is the absorbance value for 0 min, Δt is the time difference (20 min in this experiment), and ΔA is the change of the absorbance value.

5. RESULTS AND ANALYSIS

5.1 Orthogonal Test Results

The stability ESI1 of the bio-diesel fuel, which has been produced by ultrasonic emulsification methods, is an indicator test, and the analysis of the orthogonal experimental results was as follows:

Of the four selected factors, consisting of frequency, power, processing time, and ultrasonic irradiation waveform, the factor with the most influence on the stability of the emulsified fuel during the process of ultrasonic emulsification was the ultrasound time, followed by ultrasonic power, ultrasonic frequency, and lastly current waveform. The optimal operating conditions were found to be ultrasonic power 30 W, processing time 8 min, ultrasonic frequency 25 KHz, and ultrasonic wave square pulse. Under these conditions, the stability of the bio-diesel fuel prepared by ultrasonic emulsification technology was the best. Through a verification test, the stability of the ultrasonically emulsified fuel *ESI*1 under the above conditions was found to be 114.8, which coincided with orthogonal the test results.

5.2 The Influence of Ultrasonic Operational PArameters on the Stability of Emulsified Fuel

5.2.1 Ultrasound interaction time

The orthogonal experiments indicated that, in the process of emulsification, the ultrasonic processing time was the factor that had the most influence on the stability of the prepared emulsified fuel. In trials it was found that even with different ultrasonic frequency processes, the emulsion stability increased first and then decreased with the increase of time. When the processing time was 6 to 8 min, the stability was best. With further increase in processing time, the stability didn't improve obviously, but rather it declined. The above results indicated that too short or too long an ultrasonic processing time was, it is more detrimental to improve the stability of the emulsion. Under the conditions of different ultrasonic frequencies, powers, and waveforms, the optimal value for processing time was different.

Table 1 The Orthogonal Test Of Emulsified Oil Stability

	A Frequency /KHz	B Power /W	C Emulsificationtime /min	D Wave	*ESI*1
1	25	10	5	Sine	50.9
2	25	30	8	Saw-tooth	105.3
3	25	60	10	Triangular	70.5
4	25	100	15	Square pulse wave	51.3
5	50	10	8	Triangular	63.3
6	50	30	5	Square pulse wave	60.7
7	50	60	15	Sine	42.7
8	50	100	10	Saw-tooth	42.1
9	75	10	10	Square pulse wave	68.7
10	75	30	15	Triangular	51.3
11	75	60	5	Saw-tooth	40.3
12	75	100	8	Sine	68.9
13	100	10	15	Saw-tooth	46.7
14	100	30	10	Sine	71.3
15	100	60	8	Square pulse wave	89.2
16	100	100	5	Triangular	35.4
k1	69.5	57.25	46.83	58.45	
k2	52.2	76.5	81.68	58.60	
k3	52.82	60.67	63.15	55.13	
k4	57.30	49.43	48.00	67.48	
Ra	17.30	27.08	34.85	12.35	
opt	A1	B2	C2	D4	

5.2.2 Ultrasonic power

A 40 mL emulsion was confected according to the above conditions in the ultrasonic emulsification experiments. By changing the input power of the ultrasonic, the stability of the emulsion could be observed. Figure 2 compares the degrees of influence of different ultrasonic powers on the emulsion stability when there were four different kinds of frequencies and the processing time was eight minutes. When frequency and power were low, their effect on emulsion stability was good.

Usually when the intensity of ultrasonication exceeds the cavitation, further increase in the ultrasound intensity will increase the yield of the chemical reaction and make the cavitation effect increase. However, sound intensity has certain limits, beyond which, if the cavitation bubble in the expansion of the ultrasonic phase were to increase, the cavitation bubble could collapse in the compression phase of the sound wave. In this way, the chemical production rate tends to be saturated or even fall under the action of the ultrasound [7].

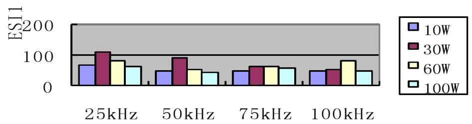

Figure4. The effects of ultrasonic power

5.2.3 Ultrasonic frequency

The ultrasonic cavitation threshold and ultrasonic frequency are closely related; the cavitation threshold increases with frequency. In other words, the higher the frequency, the more sound intensity or the sound power is needed to produce the cavitation in the liquid [8]-[10]. When the frequency is low, sounder intensity or sound power is needed to produce the cavitation in the liquid. When the frequency is low, it becomes easy to generate cavitation. At the same time, at low frequency, there is a longer time interval between the compressions of the liquid. In contrast, with the increase of ultrasonic frequency, the duration of the ultrasonic inflation phase is accordingly short, so it is difficult to generate cavitation bubbles, or even if the cavitation bubbles can be formed, but crashes due to a compression phase time shorter. In the trials, when the emulsion was 40 mL, ultrasonic action time was 8 minutes, and ultrasonic power was 30 W. By comparing the stabilities of emulsion obtained under different ultrasonic frequencies, it was found that when the frequency was 25 KHz, the emulsion stability ESI1 was 108.7, and that when the frequency was 100 KHz, the emulsion stability ESI1 was 74.2. Thus, an ultrasonic visible low frequency was more conducive to improving the stability of the emulsion. The experimental results conformed to the theoretical analysis.

5.2.4 Ultrasonic waveform

The waveforms of different excitation currents have different types of harmonic waves. The distribution and attenuation characteristics of the frequency domain and the energy of the harmonic wave are also different[11]. So in the ultrasonic emulsification process, different current waveforms also produce different cavitation effects. Usually, in order to obtain stable cavitation intensity, a sufficient pulse width is needed, and with certain pulse widths, the cavitation effect will be the best. In trials in which the volume of emulsion used was 40 mL, ultrasonic action time 8 minutes, ultrasonic power 30 W, and ultrasonic frequency 25 KHz, by comparing the stabilities of the emulsion obtained under different excitation current waveforms, it was found that when the ultrasonic excitation current waveform was square pulse wave, the conditions were most conducive to improving the stability of the emulsion.

6. CONCLUSIONS

1. The optimal ultrasonic emulsification system is to allow the free adjustment of operating parameters such as ultrasonic frequency, incentive waveform, and power in the ultrasonic emulsification process of bio-diesel fuel. They are utilized to find optimal ultrasound operating factors for different types of bio-diesel fuel.

2. The experimental(bio-oil 20% and 0# diesel 80%) results showed that among the four selected factors, frequency, power, processing time, and ultrasonic irradiation waveform, the factor that has the biggest influence on the stability of emulsified fuel during ultrasonic emulsification was the processing time, followed by ultrasonic power, ultrasonic frequency, and lastly excitation current waveform. When the operating conditions were as follows: ultrasonic power 30 W, the processing time 8 min, ultrasonic frequency 25 KHz, and ultrasonic wave square pulse, the stability of the bio-diesel fuel prepared by ultrasonic emulsification technology was the best. The stable time of bio-diesel fuel reaches to 2256 hours under room temperature.

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REFRENCES:

[1] He, J. T., Shi, Z. H., and Chang, W. D.. “Comparison of microwave-assisted and ultrasound-assisted extraction for determination of main water-soluble bioactive constituents in traditional Chinese medicinal preparation tongmaichongji by HPL-DAD,” Journal of liquid Chromatography & Related Technologies 2004,27(11), 1769-1784.

[2] Rozenberg, L. D. High-Intensity Ultrasonic Fields, Plenum Publishing Corporation, New York. 1971,16(2),35-42.

[3] Jiang, J. G., and Yang, S. H. “Groove type ultrasonic generator for improving sludge dewatering performance,” Application of Basic Science and Engineering, 2009, 12(6), 852-859.

[4] Ruan, J. Z., and Feng, L. “Preparation and application of ultrasonic emulsified diesel collector,” Coal Technology, 2011, 6(30), 147-150.

[5] Tian, J. W., and Zhang, X. L. “Study on emulsifying diesel oil from mixing emulsifying agent,” Journal of Nanchang University, 2005, 27(2), 78-80.

[6] Wang, L. M., and Wang, S. Y. “Influence of emulsification bio fuel stability of experimental study,” Eight One Farming Cultivate University Journal, 2010, 10(5), 26-29.

[7] Xue, Y. W., and Ji, M.“Ultrasonic power of the ultrasonic cracked. The influence of sludge,” Journal of Chemical Engineering, 2007,58(4), 1037-1039.

[8] Yan, Y. W., and Long, Z. L. “The variable-frequency ultrasonic generator of high-speed phase locked,” Electronic and Packaging , 2010,10(2), 35-38.

[9] Zhao, Y. Y., Feng, R., and Yang, X. Y. “Frequency to the sound of the formation of the influence of hydroxyl radicals,” Acoustic Technology, 1998, 17(1), 12-14.

[10] Petrier, C., and Francony, A. “Ultrasonic waste treatment incidence of ultrasonic frequency on the rate of phenol and carbon tetrachloride degradation,” Ultrasonics Sonochemistry, 1997. 4(1), 295-300.

[11] Lv, X. P., and Han, P. F. “The influence of ultrasonic wave on diesel emulsion,” Petroleum Chemical Industry, 2001. 30(8), 615-618.