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The Bio-Oil Production by Pulse Power Discharges

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ABSTRACT

The paper presents a new method of producing the bio-oil from the algae *Botryococcus branii* type. There are several companies in the world that produce the micro-algae oil. These are methods of centrifuging the bio-oil produced from the algae, which destroys the algae. By using the appropriate of pulse power discharge, we can separate the bio-oil from the micro-algae without damaging their structure. After separation by pulse power discharges a algae remain in good condition and are capable of further the bio-oil production. This is very important as it is quite expensive to produce and maintain a algae in good condition, so there is no point in destroying them by centrifuging. Especially now it is a very important issue for bio-fuels in the current economic crisis.

Keywords: pulse power discharge, shock wave, micro-algae, bio-oil.

INTRODUCTION

The use of pulse power discharges are used in many technical and technological fields as well as in microbiology. Plasma discharges in water are also used to cook vegetables without heat, food sterilization is used or in many fields of technology [1–3]. A new direction of application of pulse power discharges is the non-invasive separation of the bio-oil from the micro-algae (*Botryococcus branii* type) [3–5]. Under favorable conditions, the micro-algae produce the bio-oil, which must be separated without damaging the structure of the micro-algae. If this method of the bio-oil separation is achieved, the production of the bio-oil from the micro-algae is economically profitable, and also much more efficient compared to the traditional method of the bio-oil separation from the micro-algae using centrifuges that destroy the structure of microorganisms. as well as cracking or pyrolysis [6–9]. Pulse power discharges have been known for a long time and are used in many fields, but they have never before been used to separate the bio-oil from the micro-algae [10–13]. The bio-oil extraction and the problems associated with a micro-algae have been extensively described and researched [14–16]. As well as the chemical composition of the bio-oil and its suitability as a bio-fuel, many other researchers have described it [17–19]. Sometimes the micro-algae also absorb metals introduced into the water, which introduces them to the ecosystem [20]. For many years, companies have been trying to recover the bio-oil produced by a micro-algae. There is now a method to recover the bio-oil from the micro-algae. By placing the micro-algae in a centrifuge, they return the entire contents of the vessel in which they are located and in which they produced the bio-oil. Then the bio-oil was centrifuged from the micro-algae together with the water in which they were located. The centrifuged the bio-oil is separated from the water by sedimentation. The disadvantage of this method is the one-time use of the algae group for the production of the bio-oil, because the structure of the micro-algae was damaged during centrifugation. In order for the bio-oil separation process to be economically viable, it was necessary to find a method of the bio-oil separation without damaging the structure of the micro-algae. It was this factor that motivated us to look for a new non-invasive method. Using discharges in water containing the micro-algae producing the bio-oil it can be separated very quickly using a shock wave which is described in this paper.

EXPERIMENTAL SETUP

The diagram of the research stand with the power supply system is shown in Figure 1. The electrode used for impulse discharges was the electrode in the form of a wire. This proves the simplicity of this experience and the availability of a bio-oil separation device. The wire used was 3 mm in diameter. The current and voltage signals were processed by a digital oscilloscope (Tektronix DPO 71604 Digital Phosphor Oscilloscope 520A, 4 channels, 16 GHz, 50 GS/s), and the voltage across the reactor was measured with a high-voltage probe (Tektronix P6015A). The pulse power discharge current through the coaxial electrode was measured with a Rogowski coil (MODEL 6600, voltage before 0.1 Pearson current monitor, Pearson Electronics, Inc., Palo Alto, CA, USA). A schematic diagram of our experimental setup, consisting of colored water treatment, volatile organic discharge reactor removal and electrical circuit is shown in Figure 1. The MPC consists of a dc power supply a semiconductor switch a pulse transformer (PT, ratio, 1:3) a saturable transformer (ST, ratio, 1:8), saturable inductors (and) a low inductance energy storage capacitor nF, and a low-inductance pulse-forming capacitor nF. A high-speed gate turn-off thyristor (GTO, H10D33YFH, Meidensha Corp., Japan) was used to switch the primary circuit. The maximum output voltage, maximum pulse repetition rate and pulse duration of the MPC are 60 kV (positive polarity) 20 pulses per second (pps) and about 4 μs, respectively. The characteristic impedance of the MPC is less than 10. The high-speed camera with microscope was used during experiment. The type of high-speed camera with microscope was Keyence VW 9000 and tripod inclined at an angle of up to 90 degrees Keyence VH-S30B+VH-S30F, Keyence VH-Z100R lens (100-1000x) for bright/dark field observation with polarization, Additional light-source Keyence VW-L1. High-speed camera was taken 230.000 fps. All experiments were done at room temperature.

The description of the symbols in the diagram with Figure 1. The (ST) has two functions, a step-up transformer and a magnetic switch while the (GTO) witch is a high-speed semiconductor pulse generator thyristor. The semiconductor switch is a high-speed gate turn off (GTO) thyristor, (PT) it is primary tramsformer, C_o and C_1 are two capacitors and SL_1 and SL_2 are switch phase coils. The DC power supply with voltage regulation (E). The micro-algae *Botryococcus branii* were used during the experiment. The micro-algae to support the experiment were purchased from Flipkart Internet Private Limited in the amount of 150 grams. For one experiment, 10 grams of a micro-algae were used. The algae were contained in a 1 liter

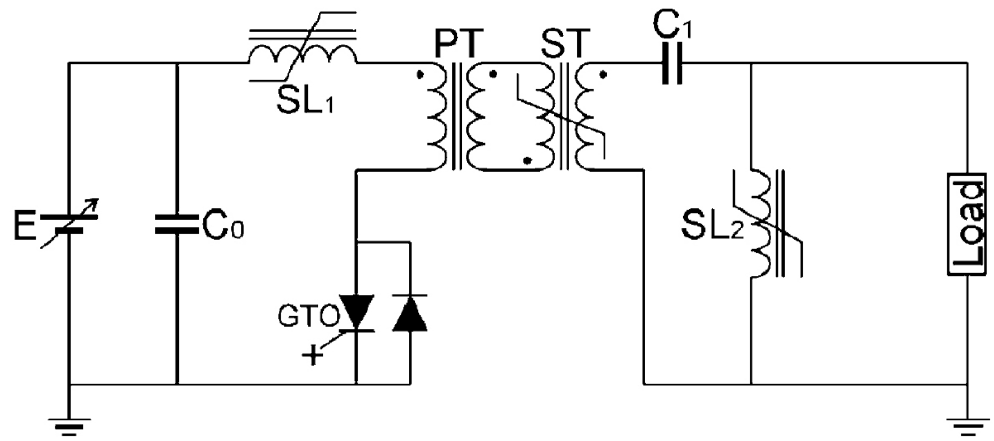

Fig. 1. A diagram of the circuit of the pulse discharge

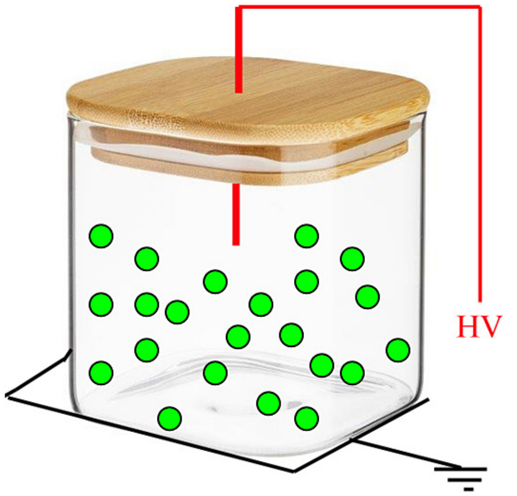

Fig. 2. A experimental setup

glass container. Pulse discharges with a power of 5 J and a frequency of 5 pps were used ten times. Experimental setup is shown in Figure 2. The distance between the electrodes was 250 mm. The grounded electrode was under the bottom of the vessel, while the wire electrode was in the vessel with the micro-algae. After separation from the micro-algae, the bio-oil was taken from the water surface with a pipette. The pH scale was measured before the start of the experiment as well as after the experiment and was 1.45. The conductivity of micro-algae water was 190 µS.

The photographs of the micro-algae were taken using a Leica M165 FC microscope with a 16.5: 1 zoom with a fluorescent attachment. The second microscope used was the Nikon Eclipse TI microscope with automatic fast focusing. The electrodes were powered by MPC 3000S-5J (magnetic pulse compressor) with a pulse power of 5J. The measured pulse voltage was 10kV and the current was 10 A. Figure 3 shows the current-voltage waveforms of the discharge pulse. This power supply has a high efficiency of about 80%.

RESULTS AND DISCUSSION

During the discharges in the water, shock wave effect was observed without additional devices. The micro-algae *Botryococcus branii* were used during the experiments. Applied to a 5J power supply and five impulses per seconds repeated ten times. The area in which the shock wave penetrated the vessel was limited only by the size of the vessel. The entire vessel with its contents was in contact with the shock wave. During impulse discharges, the shock wave moves the algae away from the electrode. The current-voltage waveforms are shows in Figure 3.

During impulse discharges in water, various phenomena are observed, such as: generation of OH free radicals from water, of UV light, production, high electromagnetic field and what was most interested for us the shock wave.

The pulse power discharge in water and the diagram of the phenomena occurring during the pulse generation are shown in Figure 4.

Before the experiment, the bio-oil was visible between the algae under the microscope it are shows in Figure 5. The microscopic photos shows the algae and the bio-oil produced between them. However, after conducting the experiment with

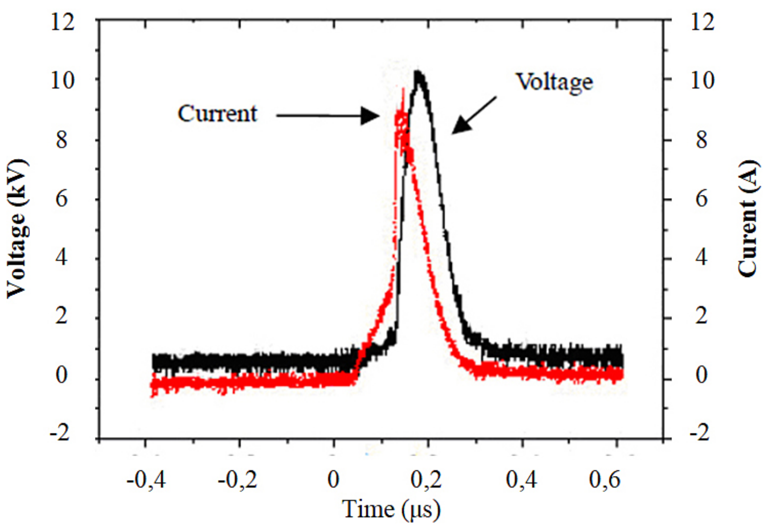

Fig. 3. The waveforms of the applied voltage to and the discharge current during discharge

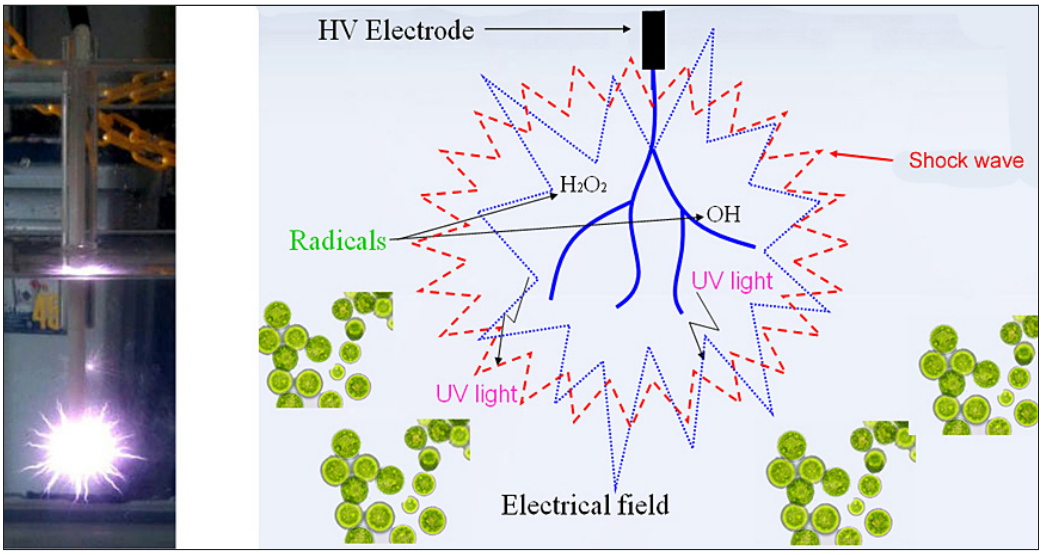

Fig. 4. The discharge phenomena in the water

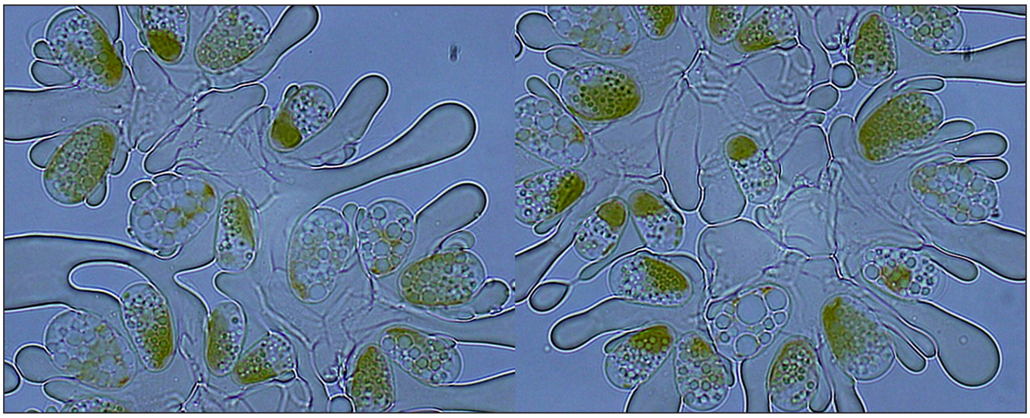

Fig. 5. The micro-algae before the experiment

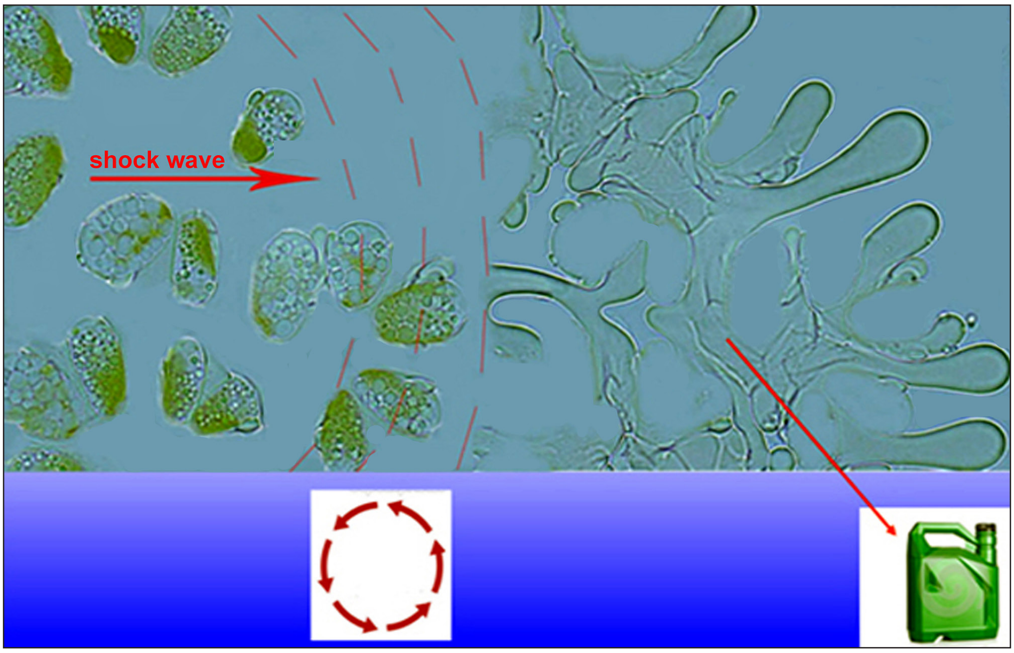

Fig. 6. The micro-algae during shock waves experiment

the frequency of 5 pps repeated ten times, the bio-oil appeared on the water surface. It was separated into the micro-algae as shows in Figure 6. Using a high speed camera, photos were taken during the pulsed power discharges, showing a shock wave passing through the micro-algae which, due to the high density of the bio-oil, pushed it out of the micro-algae.

Thanks to the use of a shock wave repeated ten times, five shots each, the bio-oil was completely separated from the micro-algae. The micro-algae are relatively small in size, around 10 μm, while the bio-oil, thanks to its high density, merges into much larger shapes, up to 200 μm. The shock wave creates high pressure that spreads throughout the entire vessel and penetrates the entire vessel with the micro-algae. Thanks to this phenomenon using a microscope it was observed that it was observed that all the bio-oil was separated from the micro-algae in the vessel. The oil was of a different density and color than the water containing the micro-algae. In Figure 6 we can see that the micro-algae are no longer surrounded by bio-oil, so the bio-oil has been completely separated from the micro-algae. The most important thing was that the micro-algae are not damaged while maintaining the appropriate power of the discharge pulse. It is shows in the Figure 6, the color and shape remain unchanged. The duration of the plasma discharge pulse was selected experimentally so that the micro-algae were not destroyed. The microscopic photos taken after the experiment show that their structure has not been damaged and they are in good condition, which allows their reuse. With plasma discharge times longer than 5 μs, the micro-algae membrane was damaged, which prevents the micro-algae from producing a bio-oil again. The micro-algae have not been damaged so the process is a closed and repeatable process. After separating the bio-oil, the micro-algae return to the tanks where they have the appropriate conditions for growth and a bio-oil production. The cost-effectiveness of this process pays off because many Bio-Mass Production companies that use centrifugation, pyrolysis or cracking to separate the bio-oil deal with it pre-industrial even though after the bio-oil separation, the micro-algae are destroyed and unable to further produce the bio-oil again. The experiment was repeated three times and the result was repeated. One experiment took about a few minutes to complete with preparation. The micro-alga *Botryococcus branii* produces hydrocarbon oils at 25–75% of its dry weight and is a promising source of bio-fuel feedstock. In our case, 6 grams of bio-oil were obtained, which was an efficiency of 60% in relation to the weight of the micro-algae used in the experiment.

Table 1. Hydrocarbon Oil Constituents of *Botryococcus braunii*

Compound	% mass
Isobotryococcene	4%
Botryococcene	9%
$C_{34}H_{58}$	11%
$C_{36}H_{62}$ (isomer A)	34%
$C_{36}H_{62}$ (isomer B)	4%
$C_{37}H_{64}$	20%
Other hydrocarbons	18%

A study carried out by micro-algae experts tested the oil produced by the micro-algae *Botryococcus branii* type "A". The results showed that this bio-oil contains aliphatic hydrocarbons from C29 to C34, while there are only traces of C18 fatty acid. The micro-algae *Botryococcus branii* have been researched for the using of this bio-oil for the production of the bio-fuel. The chemical composition of bio-oil is presented in Table 1 [21]. The research was carried out under laboratory conditions at the Kumamoto University in Japan, the results are very satisfactory.

CONCLUSIONS

The experimental results showed that the water conductivity (190 μS) and pH (1.45) were measured before and after the experiment and both parameters were unchanged. The use of pulse power discharge (power 5J) was effective in separating the bio-oil from the micro-algae by the shock wave phenomena. By observing the algae under a microscope, it can be ascertained the micro-algae do not change their color or shape which confirms their good condition. After the experiment, the micro-algae are not damaged and are able to further produce bio-oil again. Not only the power of the applied pulse power discharges plays an important role but also the duration of the impulse that times longer than 5 μs, the micro-algae membrane was damaged. The separated a bio-oil stays on the surface of the vessel, which makes it easier to drain it. The results show that the primary mechanism for the separation of the bio-oil from the micro-micro-algae was the shock wave.

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