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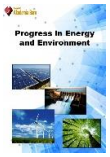

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Short Communication

Preliminary investigation on the disruption of microalgae cell wall using Vortex Induced Vibration (VIV)

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Abstract

Scenedesmus sp. is industrially known for its high lipids content that can be used in biofuels production. Most of the conventional mechanical methods to disrupt the microalgae cell wall use high frequency approaches. The conventional high frequency methods have few disadvantages which are high energy consumption, high cost and application of solvents which are the cause of environmental pollution. In this paper, a low frequency method called vortex induced vibration (VIV) is proposed to replace the conventional mechanical methods to disrupt microalgae cell wall. An experimental rig has been designed and fabricated for this experiment. Based on the experiment, the result shows that VIV method has the possibility to break microalgae cell wall since the turbidity decrease throughout the days.

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1 Introduction

Microalgae is photosynthetic microorganism that can be largely found in aquatic habitat like oceans, lakes, pounds and even wastewater. The capabilities of microalgae are withstood extensive temperature, salinities, pH values and light intensities [1]. The advantages of microalgae compare to other feed stocks in producing biodiesel are high in content of the lipid and growth rate, and can be cultivated in seawater or freshwater without competing for agriculture land. Comparing to other food crops, the growth rate of microalgae is 5 to 10 times faster and the lipid productivity of microalgae can be 15-300 times higher [2].

Scenedesmus is formerly known as *Scenedesmus obliquus* and is identified as freshwater green microalgae [2]. There are three primary categories in *Scenedesmus* taxonomy which are *Acutodesmus*, *Desmodesmus*, and *Scenedesmus*. Among green algae, *Scenedesmus* is known for its high biomass production which lead to the high lipid and fatty acid productivity [2]. Besides, Chen et al. [3] have found that *Scenedesmus* has higher efficiency in capturing CO_2 compares to other algae. *Scenedesmus* is high in resistance because of the thick cell wall that has a characteristic of trilaminar structure. Even though it is thick in cell wall, but *Scenedesmus* is easily cultivated and can withstand wide range of environmental conditions [4]. Therefore, *Scenedesmus* is chosen for this experiment due to those factors.

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There are several mechanical cell disruption methods for microalgae that have been introduced which include high pressure homogenization, ultrasonication, bead milling, pulsed electric field, microwave and high-speed homogenization. These methods involve pumping of cell suspension [5], cavitation from energy of high frequency acoustic waves and jet stream [6], collision of small beads [7], high voltage electric pulse [8], high pressure bubbles [9] and high-speed agitation [10]. Table 1 shows the pros and cons of mechanical methods for disruption of microalgae cell.

Table 1 The advantages and disadvantages of conventional mechanical methods.

Mechanical method	Advantage	Disadvantage
Bead milling	High rupture efficiency, high productivity, reproducibility, and temperature management [5].	High temperature rising, poor settings, high chance of contamination [11].
High pressure homogenization	Scalability, reproducibility and toxic substance free [12].	High energy demand [12] high cost [9].
Ultrasonication	Disruption can happen at low temperature [13].	Increasing temperature will destroy other intracellular metabolite [5], temperature control will decrease effectiveness of cell disruption significantly [13].
Pulsed electric field	Gentle disruption technique, scalability and combination with other disruption methods [7].	Release of metabolites/compound from the disrupted cells due to the increased conductivity will cause the increase in temperature [7].
High speed homogenization	Short processing time and the ability to tolerate with high dry cell well concentrations [5].	Difficult for scaling in large scale industry due to the HSH rotor-stator apparatus, aggressive nature of cell disruption [7].
Microwave	Short processing time, scalability, high efficiency, low energy consumption and low risk of metabolite denaturation [5,14,15].	High maintenance cost for industrial scale land, the need of cooling before continues processing in order to maintain the product integrity [13].

Vortex Induced Vibration (VIV) is a phenomenon that takes place after vortex shedding occurs. The vortex shedding creates significant forces in drag and lift to move the cylinder in large amplitude. It is assuming that this low frequency method is able to generate efficient mixing [16] and has the potential to break the microalgae cell wall due to the strong shear forces that are created during the vibration. Therefore, in the present study, the use of VIV is proposed, which to our best knowledge, has not been attempted before to disrupt the cell wall of microalgae. The proposed technique is useful especially for the growth of microalgae in offshore and river (water). In fact, there is a system to grow the microalgae in offshore by using enormous floating infrastructure in marine bay. It is named as OMEGA (Offshore Membrane Enclosure for Growing Algae) [17]. To process the microalgae biofuel from the OMEGA, transportation of the microalgae to the land is inconvenient. The literatures have shown that currently most of the separation processes have to be conducted separately in laboratory. Therefore, the present study proposes a cell wall disruption technique which can be done directly on field.

2 Methodology

2.1 Microalgae Strain and Culture Condition

Scenedesmus has been selected for this experiment since it has high lipid content and can be cultivated easily without any contamination. Sample of Scenedesmus was supplied by Algae Ikohza in Malaysia-Japan International Institute of Technology (MJIIT, UTMKL). *Scenedesmus* (CN01, MJIIT-UTM, Malaysia) was cultivated in AF6 medium. Alkaline medium is preferred in cultivation of microalgae. The range of optimal pH is between 8.2 to 8.7 [18]. Therefore, the pH of the AF6 medium was adjusted to pH 8±0.2. Culture was grown at 30±5°C with white, fluorescent lamp at 1000µmol photons m-2 s-1 with continuous aeration of CO_2. The culture was grown for 6 days and harvested during stationary state. Stationary state is the state when the population size of microalgae remained constant even though some cells continue to divide and others to die. It is the state before decline of death phase [19].

2.2 Vortex Induced Vibration Rig Design

A simple model of rig was designed using solid modelling computer-aided design (CAD). The rig was equipped with a clamp where the sample can be placed at. It used a simple mechanism where the shaker can move in vertical direction to produce vertical vibration, mimicking the motion of VIV. To stimulate lock in condition of the VIV, the vibration was set at low frequency. The range of the frequency designed for the rig was available from 1 to 20 Hz, and the accessible amplitude range was from 2 to 6 cm.

As overall, the rig converts the rotational motion from motor to linear motion on the clamp. The clamp moves in vertical direction, where the microalgae sample can be attached at the clamp. The microalgae sample that was placed in a cylindrical falcon tube was experiencing vibration. This vibration was considered as VIV, a low frequency method. Fig. 1 shows the schematic operation of rig.

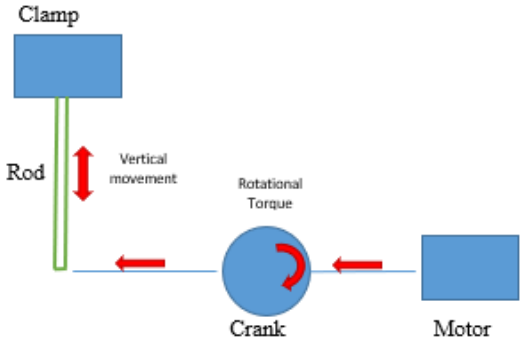

Fig. 1 Schematic operation of rig.

2.3 Turbidity Measurement

Turbidity is the measurement method used to identify the possibility of VIV in breaking cell wall of microalgae. Turbidity has a correlation with light scattering. In order to measure the growth of pure sample, the method used is light scattering [20]. According to Koch [21], light scattering measures the molecular content instead of the number of cells. Spectrophotometer is used in order to measure turbidity and estimate the cell biomass. The principle of light scattering is according to the cells' light absorption at a definite wavelength where the light that is not scattered can be detected. The intensity of light beam is inversely proportional to the number of cells in light path where this gives an indirect correlation of the amount of biomass in the sample. When the number of cells in the suspension increases, the light absorbance increases. As a result, less light can be detected [22]. If a cell wall is ruptured, the shape of the microalgae cell wall will change into irregular, and hence reduce the solid mass and the turbidity [23].

In the present study, UV-VIS spectrophotometer was utilized and the suspended sample of *Scenedesmus* was put in cuvette quartz. There are several common wavelengths used in microalgae research which are 565 nm to determine biomass concentration, 680 nm to measure chlorophyll absorption and 750 nm to measure turbidity [19]. Therefore, wavelength of the spectrophotometer was set at 750 nm in this study.

3 Results and Discussion

3.1 Rig Structure and its Operation

Fig. 2 and 3 show the full design of VIV experimental rig. It consists of 5 main parts which are base, shaft, connecting rod, crank, and clamp. The rig is designed to have 3 amplitudes, namely 2, 4 and 6 cm. The reason of setting these amplitudes is based on the non-dimensional maximum amplitudes that usually occurred in VIV phenomenon, which is within amplitude range from 1 to 1.3 [24]. Since the selected cylinder tube is 2.8 cm, the mentioned amplitudes are selected for the rig.

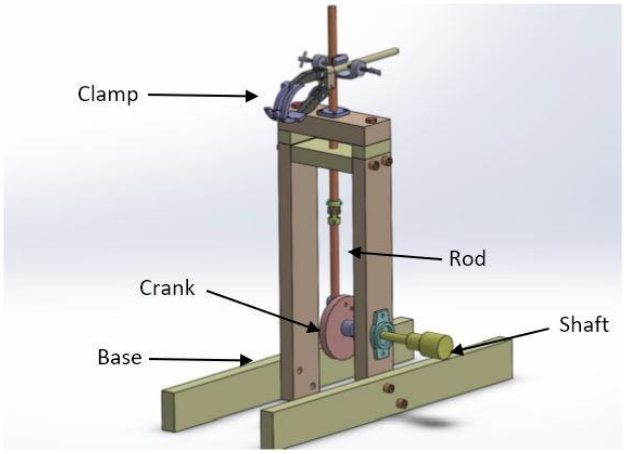

Fig. 2 Assembled part of base, shaft, crank, rod, and clamp.

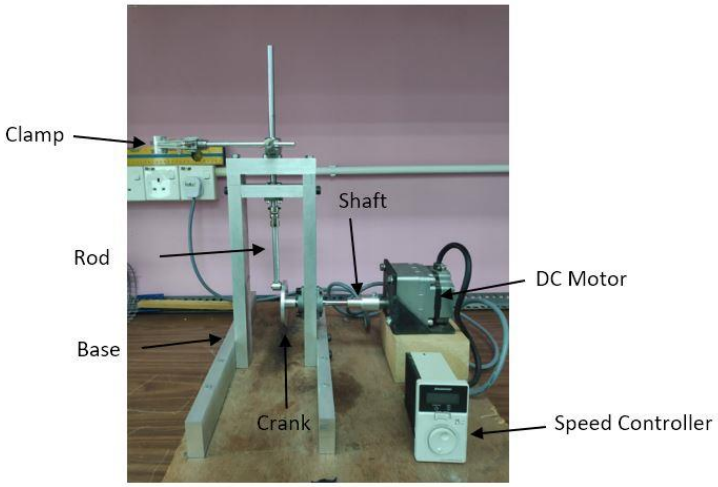

Fig. 3 Full design of VIV rig.

Brushless DC Motor is used with a driver in order to channel the electrical power into a force to the connecting rod. The function of driver is to control speed within a range of 80 to 4000 r/min. In this experiment, the speed was set at 600 r/min which was equals to 10 Hz. The Brushless DC motor can supply output power up to 120W.

3.2 Application of VIV

The microalgae sample that has reached stagnation stage is then placed on VIV experimental rig. The sample is placed into a cylindrical falcon tube where it is clamped. For this experiment, VIV is applied starting on day 6 of microalgae growth, and the data is collected on day 8,10 and 12. Frequency used is 10Hz with the amplitude of 6cm. The optimum temperature range for microalgae culture is between 20°C to 30°C. If the temperature more than 35°C, it can be lethaled for the growth and the temperature lower than 16°C will slow down the growth. Hence, the temperature is controlled at 25°C for the optimum growth of *Scenedesmus* [25].

3.3 Turbidity

Fig. 4 shows the comparison of microalgae turbidity with and without VIV motion. Turbidity 1 is the turbidity of microalgae without VIV while Turbidity 2 is with application of VIV. The turbidity for T1 and T2 are taken on day 6,8,10, and 12 only. The reason of applying VIV from day 6 to 12 is because the stagnation stage is started during that period [26]. After day 13, the microalgae may start its dead phase depending on the prepared medium. Therefore, data after day 13 may not be reliable.

Based on Fig. 4, turbidity of microalgae that is not subjected to the VIV is remained consistent from day 6 to 12. The asymptotic pattern is similar to the existing study [26]. However, for turbidity of microalgae that implement VIV, the graph is decreasing, indicating that VIV is able to disrupt the cell wall. In fact, the motion of VIV creates some sloshing effects in the falcon tube, where it generates periodic fluctuations that could break off the cell wall of microalgae. The difference of turbidity between day 6 and day 12 is 0.103 which equals to 9.93% of reduction.

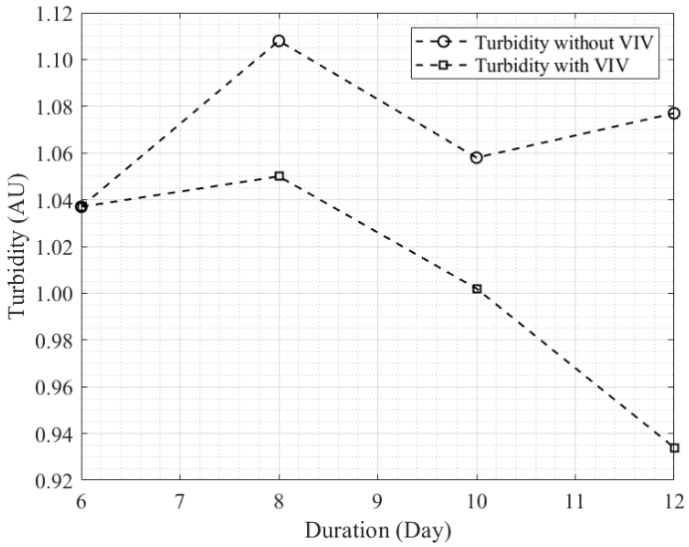

Fig. 4 Turbidity comparison with and without VIV.

4 Conclusion

Vortex Induced Vibration (VIV) is a low frequency mechanical method that is used for this experiment. VIV is proposed in order to identify the ability of a low frequency method to break microalgae cell wall. *Scenedesmus* is chosen as the microalgae sample in the present study since it has higher lipid content, easier to be cultivated and does not contaminate easily compared to other microalgae sample. In order to achieve the objective to design an experimental rig, CAD is used to design the rig before fabrication. Through the turbidity test, the result shows an encouraging outcome. The difference of turbidity between day 6 and day 12 is 0.103 which equals to 9.93% of reduction after applying VIV starting from day 6. The decrease of turbidity shows that the solid biomass inside microalgae is able to get into the outer layer since the cell wall of *Scenedesmus* has been broken using VIV. It shows that a low frequency method has the potential to break the cell wall of *Scenedesmus*. The proposed future work is to investigate the possibility to integrate the use of enzyme with VIV to accelerate and improve the disruption rate of microalgae cell wall.

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Declaration of Conflict of Interest

The authors declared that there is no conflict of interest with any other party on the publication of the current work.

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