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Preliminary Design of Algae Cultivation Bioreactor

Syahidzil Mokhaizil Sulaiman[1], Mohammad Fahmi Abdul Ghafir[1*], Bukhari Manshoor[1], Norshuhaila Mohamed Sunar[2,3]

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun HusseinOnn, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA
[2]Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA
[3]Research Center for Soft Soil (RECESS), Universiti Tun Hussein Onn, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

Email: *fahmi@uthm.edu.my

Abstract: The aim of this project is to comprehensively study the background design of an algae cultivation bioreactor, identify its working principle, and develop engineering drawings while conducting a design analysis of an existing algae bioreactor cultivation in RECESS, UTHM. The objective is to enhance the efficiency and productivity of the bioreactor system for sustainable algae cultivation. SolidWorks is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that will be used to create detailed and accurate 3D models of an algae cultivation bioreactor. The 3D designs for the components will be construct before the analysis using Ansys. Two analyses will be conducted using it which is the thermal analysis on the solar panel and the hydrostatic pressure analysis on the water tank. The result is will show either that the water tank was constructed and safe to use. Both of the analyses will be conducted using Ansys Workbench and helped to understand the behaviour of the water tank and the solar panel.

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*Corresponding Author:

Mohammad Fahmi Abdul Ghafir,
Faculty of Mechanical and Manufacturing Engineering,
University Tun Hussein Onn, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA
Email: fahmi@uthm.edu.my

1. Introduction

Diverse water species that may photosynthesize include algae. Depending on their size, they are categorised as macroalgae or microalgae. Macroalgae are bigger than microalgae and can be seen with the naked eye, whereas microalgae must be viewed under a microscope. There are many different habitats where algae may be found, including freshwater, saltwater, and even on land. They come in a variety of shapes, including spheres, cylinders, and plates, and can be either unicellular or multicellular. Numerous algal species provide food for other aquatic animals and are crucial for the synthesis of oxygen, the nitrogen cycle, and carbon sequestration.

Algae, on the other hand, has several potential human advantages. Some algae species are utilized as food and dietary supplements, especially in Asian cultures where they have been for millennia. They're also high in vitamins, minerals, and antioxidants. Some algae species have been studied for their capacity to remove contaminants from water as well as their potential use as biofuels. Algae are also used to make cosmetics, medicines, and other items. Algae are an important area of research due to the potential benefits it can bring to human, from medicine to environment. There is still a lot to learn about these organisms and the benefits they can provide to humans.

In terms of the bioreactor design, this research is to study and analyze the background design, working principle, and engineering aspects of algae cultivation bioreactors. The specific objectives include understanding the design features and components of algae bioreactors, identifying the principles behind their functioning and cultivation systems, and developing engineering drawings and conducting design analysis of existing algae bioreactors. By achieving these objectives, the research aims to enhance the understanding of algae cultivation bioreactors and contribute to their further development and optimization in the field of algae-based biofuel production, wastewater treatment, or other applications related to algae cultivation.

Demand for fossil fuels is sky-rocketing and fossil fuels are a limited, non-renewable energy source. Given these advantages, algae look to be a feasible alternative feedstock for biodiesel production. The purpose of this study is to investigate and analyse the background design, working principles, and engineering features of algae culture bioreactors.

Listed below is the objective of the study,

i. To study the background design of algae cultivation bioreactor.
ii. To identify the working principle for cultivation system of bioreactor.
iii. To develop the engineering drawing and conduct design analysis of existing algae bioreactor in RECESS, UTHM.

Scope of the study aimed is as follows,

i. The research will focus on the algae bioreactor located in RECESS, UTHM.
ii. The parameter of the area for the project will includes understanding the purpose of the 3D design, and the constraints on the design.
iii. The 3D design of the algae system will be done through SolidWorks software.
iv. The design analysis will be conduct using Ansys Workbench.

The study will aim to make a 3D design and making an analysis for the algae cultivation, which will be beneficial to many parties, especially those in the biofuel production industry and many others. Algae cultivation can be cost-effective method for producing biofuels, food or other products, and a preliminary design of a bioreactor can help to identify the most efficient and cost-effective methods for cultivation. The industry can also collaborate with research institutions, universities and other to develop a new design or technologies and improve the algae cultivation process. As student, this project can give a sense of the real-world applications of algae cultivation and bioprocess engineering and also learn about the different types of bioreactor and their specific applications, as well as the principles of bioreactor design.

2. Methodology

Solidwork is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systemes. It also is a parametric feature-based system, which means that the dimensions and relations between the parts are used to define the geometry of a model. Solidwork also can be used to create detailed and accurate 3D models of an algae cultivation bioreactor. To comprehend the structure of the design better, all 3 modes of drawing was used. These modes include parts, assembly, and drawing

While Ansys Workbench is a graphical user interface (GUI) for engineers to utilize to build and manage engineering simulations. It serves as a single database for all of your simulation data, such as models, results, and reports. It has several tools that make it simple to design and maintain engineering simulations, including A project schematic for visualizing and organizing your simulation process. A parametric manager that allows you to explore many design situations fast and simply. A solver manager that lets you submit simulations to local or remote solvers. A results viewer that allows you to examine and evaluate the outcomes of your simulation. A report generator that allows you to generate professional-looking reports based on your simulation findings. Two analyses will be conduct which is the thermal analysis on the solar panel and the hydrostatic pressure analysis on the water tank.

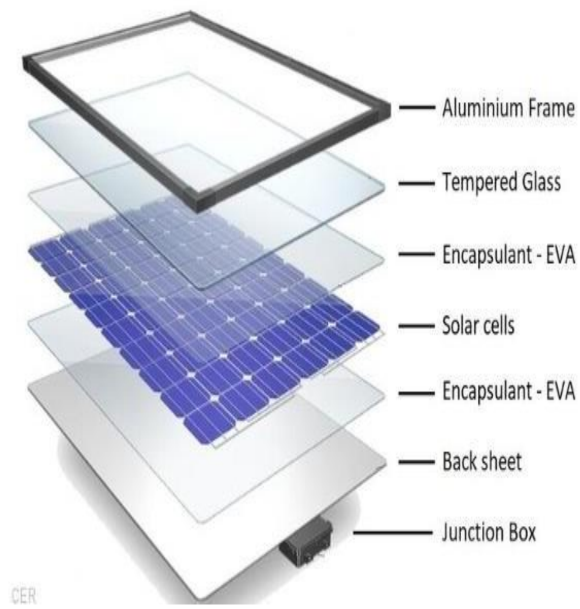

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Fig. 1 - Material for each component of the solar panel

Table 1 - Properties of the layer for solar panel

	$K\ (\frac{W}{m.k})$	$\rho\ (\frac{kg}{m^3})$	$C_p\ (\frac{J}{kg.k})$
Glass	1.8	3000	500
EVA	0.35	960	2090
PV	148	2330	677
PVF	0.2	1200	1250

Every material for each component of the solar panel has it owns mechanical properties (see Table such as the density, isotropic thermal conductivity, and specific heat.

3. Results and Discussion

The stage of the development phase where all the geometric design aspects are documented, including a rough estimate of the chosen design solution, for input to the detailed design stage is known as preliminary design.

3.1 SolidWorks Results

SolidWorks result allows to analyse the designs to ensure they meet the desired objectives. By performing analysis, this 3D design can verify if their designs are capable of meeting the working principle for the algae cultivation systems.

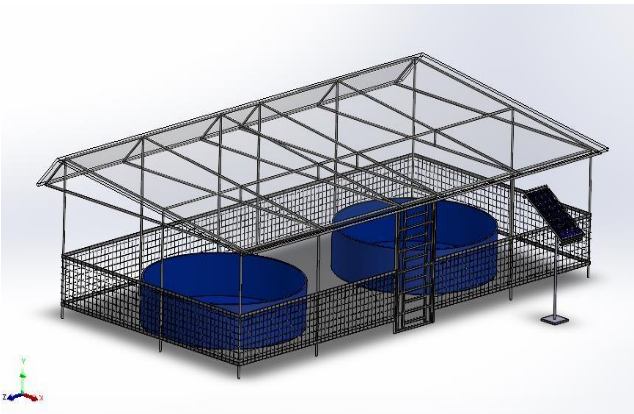

Fig. 2 - Full Assembly

3.2 Ansys Result

Two analyses will be conduct which is the thermal analysis on the solar panel and the hydrostatic pressure analysis on the water tank. Thermal Analysis on solar panel. From the analysis, the temperature distribution throughout the solar panel's surface can be visualised. This study is helpful to determine areas of high heating or cooling and evaluating the performance of the thermal management system on the panel. It also can visualise the heat flux, which is the rate of heat transfer per unit area. This data may be used to optimise cooling systems or analyse thermal gradients by identifying locations of high heat transfer.

Table 2 - Result for Thermal Analysis

	Result		
	Temperature	**Temperature 2**	**Total Heat Flux**
Minimum	87.736 °C	94.856 °C	50.929 W/m²
Maximum	108.95 °C	108.5 °C	96131 W/m²
Average	101.36 °C	103.66 °C	15151 W/m²

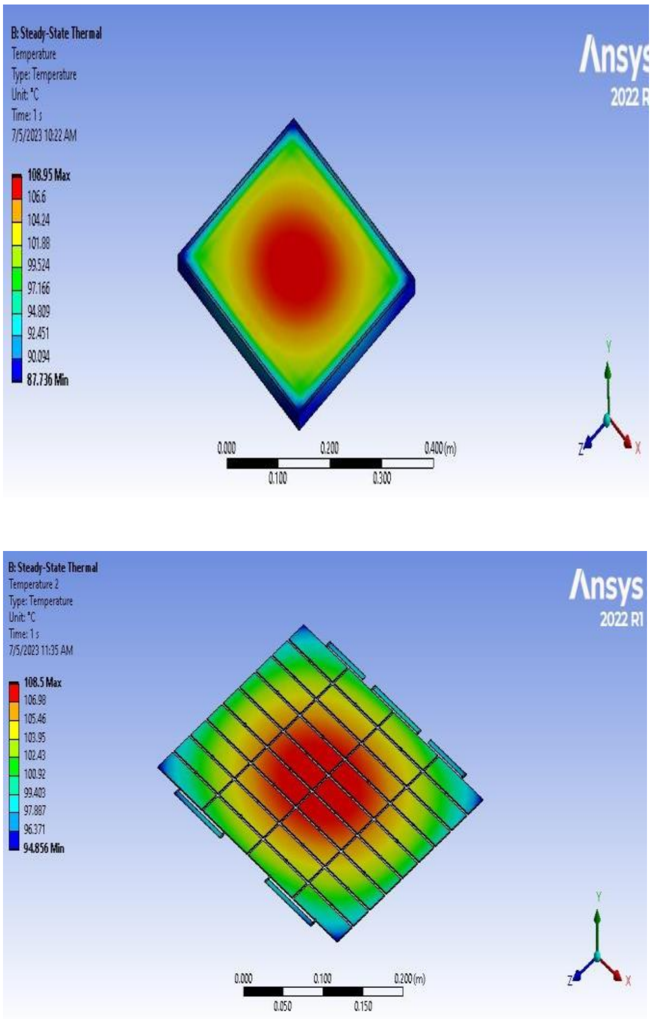

Fig. 3 - Temperature Distribution

The temperature distribution describes the difference in temperature throughout the system or

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product under consideration. The minimum 87.736°C occurs around the frame, while maximum 108.95°C occurs the EVA layer. The primary purpose of the EVA layer in solar panels is to protect and cover the photovoltaic cells from external variables such as moisture, dust, and mechanical stress.

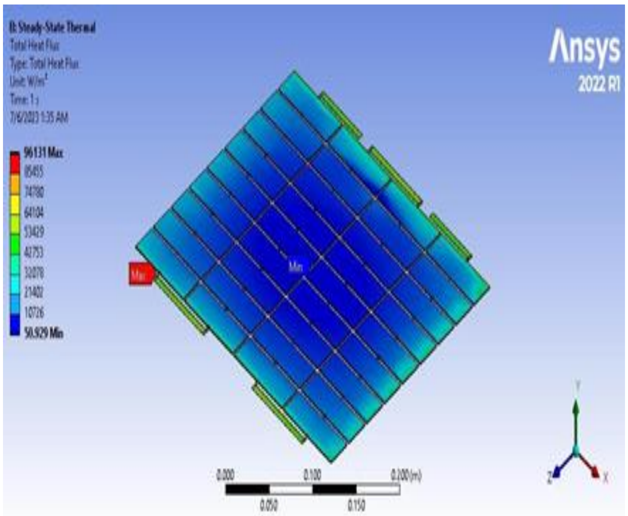

Fig. 4 - Temperature on PV Layer

The maximum temperature is 108.5°C on PV layer at occur in the middle, while minimum temperature is 94.856 °C. A PV (photovoltaic) layer is an important part of a solar panel. It is also known as a solar cell or photovoltaic cell. The purpose of it is to use the photovoltaic effect to directly turn sunlight into electricity.

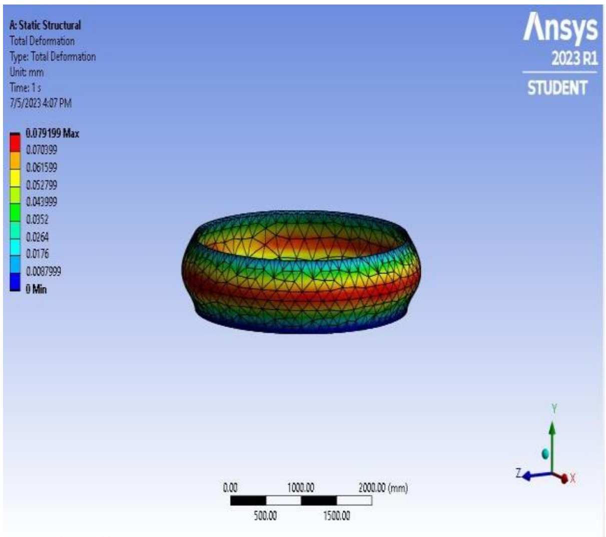

Fig. 5 - Total Heat Flux on PV Layer

The quantity of heat energy transmitted to a solar panel by sunlight is referred to as the heat flux. While a solar panel's primary function is to create energy, it will undoubtedly absorb some heat as a consequence. The maximum heat flux is 96131 W/m², while the minimum is 50.929 W/m².

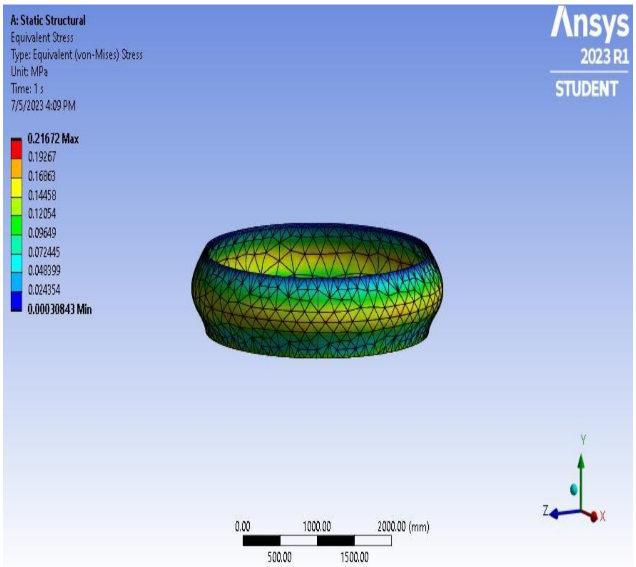

Fig. 6 - Total Deformation

Under static conditions, the analysis assists in identifying the distribution and magnitude of pressures within a fluid or liquid-filled system. The weight of the fluid column above a specific location in a fluid determines the hydrostatic pressure at that point. It is determined by the fluid's density, gravity's acceleration, and the depth of the point below the fluid's free surface.

Table 3 - Result for Hydrostatic Pressure

Result			
	Total Deformation	**Directional Deformation**	**Equivalent Stress**
Minimum	0. mm	- 0.070051 mm	0.0003084 MPa
Maximum	0.079199 mm	0.074599 mm	0.21672 MPa
Average	0.021601 mm	0.00013764 mm	0.059373 MPa

Total deformation is the entire change in size or shape caused by the application of hydrostatic pressure to a material or structure. It takes into consideration the combined effect of deformations in all directions. The maximum for total deformation is 0.079199 mm, while the minimum is 0 mm.

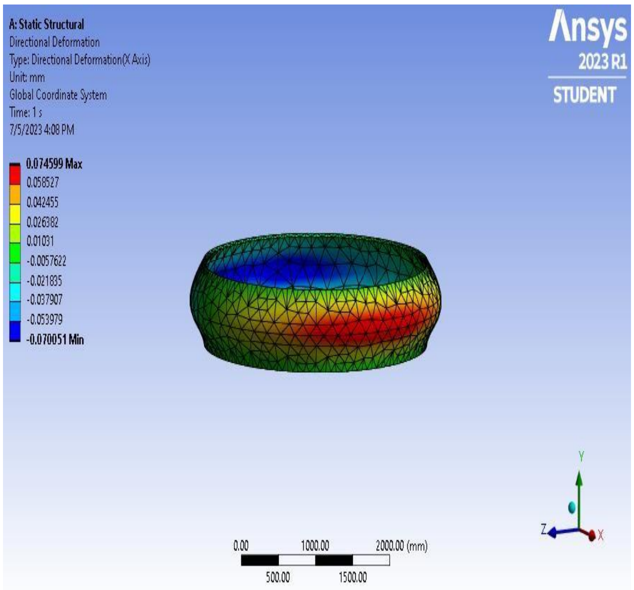

Fig. 7 - Directional Deformation

Directional deformation is stated as a ratio or percentage of the original length or dimension. The maximum is 0.074599 mm, while the minimum is -0.070051 mm. It measures the relative displacement or elongation of a material that results from applied hydrostatic pressure in a given direction.

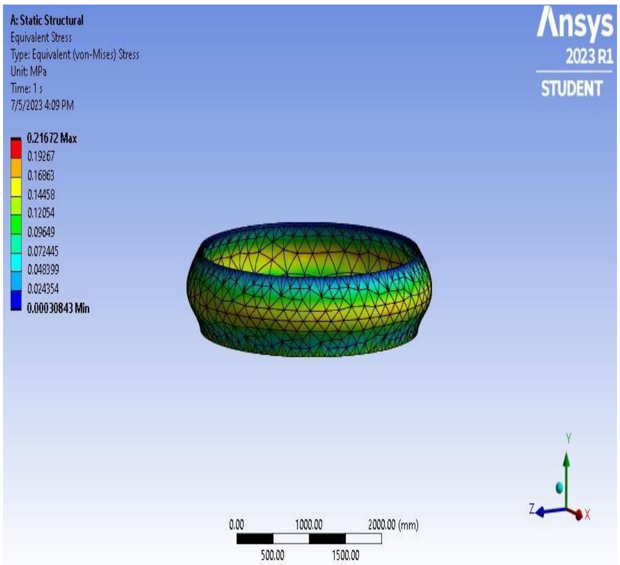

Fig. 8 - Equivalent Stress

Based on the result obtained, the maximum stress is 0.21672 MPa while the minimum is 0.0003084 MPa. Equivalent stress is the stress state that has the same effect on the material as its actual stress state.

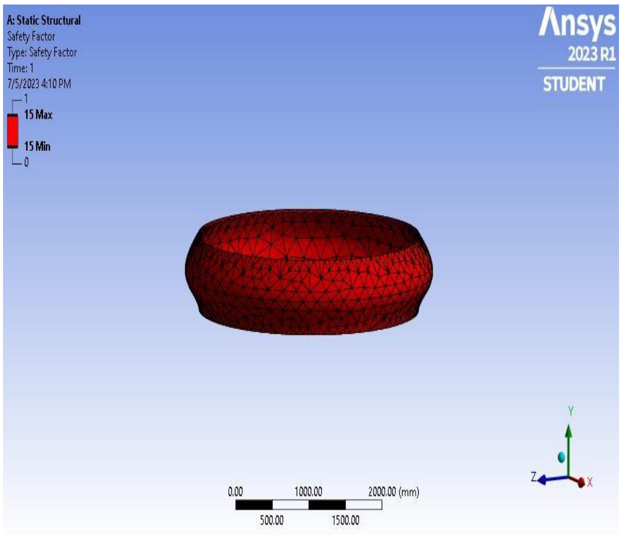

Fig. 9 - Safety Factor

In hydrostatic pressure analysis, a safety factor analysis is used to assure the structural integrity and safety of a system or component that is subjected to hydrostatic pressure. The safety factor is 15. A higher safety factor has a relationship with a lower total deformation because it shows greater resistance to deformation and more rigid construction.

4. Conclusion

This research examined the design and operation of bioreactors for cultivating algae. By reviewing existing literature, valuable insights were gained regarding the factors influencing bioreactor design and functionality. The study focused on key components such as light resources, aeration, and temperature regulation. The findings provide a basis for further advancements in the field, enabling the development of optimized bioreactor designs and improved cultivation strategies. This research contributes to meeting the demand for sustainable energy sources and valuable algae-derived products. This project successfully developed a 3D design of an algae bioreactor at RECESS, UTHM. The design provided a comprehensive representation of the bioreactor's components, dimensions, and structural layout. Two analyses were conducted using Ansys Workbench: a thermal analysis on the solar panel and a hydrostatic pressure analysis on the water tank. The thermal analysis revealed the maximum and minimum temperatures and total heat flux, indicating the solar panel's ability to perform well in high- temperature conditions and maintain optimal energy output. The hydrostatic analysis assessed deformation, stress distribution, and safety factors, confirming that the water tank was constructed with a significant safety margin. These analyses contributed to a better understanding of the bioreactor's behavior and performance.

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References

[1] A. Vidyasagar, "What Are Algae?" LIVESCIENCE, 2021.https://www.livescience.com/54979-what-are-algae.html

[2] "Algae | Botany Basics | Biology Dictionary." https://biologydictionary.net/algae/ (accessed Jan. 10, 2023).

[3] "Causes and Ecosystem Impacts | Harmful Algal Blooms | CDC." https://www.cdc.gov/habs/environment.html (accessed Jan. 11, 2023).

[4] S. Yadala and S. Cremaschi, "Design and optimization of artificial cultivation units for algae production," Energy, vol. 78, no. July, pp. 23–39, 2014, doi: 10.1016/j.energy.2014.06.001.

[5] B. Wang, Y. Li, N. Wu, and C. Q. Lan, "CO2 bio-mitigation using microalgae," Appl. Microbiol. Biotechnol., vol. 79, no. 5, pp. 707–718, Jul. 2008, doi: 10.1007/S00253-008-1518- Y/METRICS.