Needs Assessment

Senior Design Project (EML 4551C) - Fall 2013 Deliverable
Team 07 - Microalgae Photobioreactor

Prepared By:
Markus Dillman
Stephen Kassing
Diego Soler
Matthew Vedrin

Project Advisors:
Dr. Juan Ordonez
Department of Mechanical Engineering, FSU
Dr. José Vargas
Department of Mechanical Engineering, UFPR

Course Professors:
Dr. Chiang Shih
Department of Mechanical Engineering
Dr. Kamal Amin
Department of Mechanical Engineering

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Department of Mechanical Engineering, Florida State University, Tallahassee

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1.0 Problem Statement

The customer defined the problem statement in the project proposal as:

> "The UFPR-FSU senior design teams have worked in the past with photobioreactors that work in batches. Growth media is added initially to microalgae to be grown in the photobioreactor for a period of approximately 15 days. At the end of that period the biomass is extracted and a new batch starts.
>
> We anticipate enhance biomass productivity by using a continuous growth system (as opposed to batch) in which biomass is continuously extracted as new cells grow attempting to maintain a nearly constant ideal cell concentration within the photobioreactor. Media (nutrients and water) will need to be added in the necessary amounts to make up for the extractions.
>
> The implementation of a continuous system, requires at least: (i) a concentration sensor, (ii) an automatic unit of media supply, and (iii) a biomass extraction unit. The concentration sensor was partially developed by the 2012-2013 team (see link under background), and it will be further enhanced as part of a master thesis. What you are asked to design is the units (ii) and (iii), and amend the previously developed concentration sensor (i)."

Thus, the customer needs a way to transform the photobioreactors' current "batch" growth systems into "continuous growth systems." In order to achieve this, the customer is requesting the design or development of an "automatic unit of media supply" and a "biomass extraction unit", as well as an improvement to the "previously developed concentration sensor."

2.0 Background and Justification

Coal, petroleum, and natural gas are all nonrenewable resources commonly used today. As consumption continues to increase, these resources are becoming more and more unsustainable. If changes are not made or alternatives are not found, these resources will eventually run out, crippling infrastructures and industries on a global scale. In addition, greenhouse gasses will continue to increase and negatively affect the environment. New methods of energy production and consumption must be implemented before significant consequences occur. Alternative fuels, such as biofuels derived from oils in crops, present one solution to this energy problem. Some examples of biofuel crops are corn, soybean, sugar cane, canola, and microalgae. Microalgae are the only biofuel that can completely replace our existing fuel sources. Microalgae take little room to grow compared to crop biofuels and produce biomass much quicker than other crops. According to Yusuf Chisti, within twenty-four hours, microalgae can double its biomass (*Biodiesel from Microalgae*).

The Florida Agricultural and Mechanical University – Florida State University College of Engineering (FAMU-FSU COE) in Tallahassee, FL, USA and the Federal University of Paraná (UFPR) in Curitiba, Paraná, Brazil started a partnership on senior design projects in 2005. The projects are unique in that they require international collaboration between universities. In this section, brief reviews of the past projects are explained. We will focus on the projects from 2010-present because the 2010 group was the first team to implement the microalgae in their objectives. The designs and prototypes mentioned below are currently at the FAMU-FSU COE. These were created based on existing photobioreactor systems and research at UFPR.

Figure 1 shows the Trigenerator System with Photobioreactor. This was completed by the 2011 Senior Design team. (Senior Design Project)

Starting in 2010, the combined team, consisting of a group at UFPR and a group at FAMU-FSU COE, developed a new way to monitor the effects of carbon dioxide on microalgae. The FAMU-FSU COE team built a bench-top airlift photobioreactor. The CO_2 was supplied though the bottom of the airlift tubes, rose through the algae, and exited out the top. The microalgae concentration was monitored by counting the cells under a microscope and the optimal amount of CO_2 to get the most cell growth was determined (*Senior Design Proposal*).

In 2011, the team implemented this knowledge of the effect of CO_2 on microalgae into a trigeneration system. The trigeneration system was built by the 2005 senior design team. It is a system that created hot water, electricity, and refrigeration from fuel in an internal combustion engine. The final project is shown in fig. 1 (*Senior Design Proposal*).

The 2012 team went in a different direction. They built a mini-photobioreactor at the FAMU-FSU COE, designed as a small-scale prototype of the one in Brazil. In addition, they designed and implemented concentration and mass flow rate sensors to determine the optimal time to extract the microalgae in order to obtain the most biomass before it starts to die. The use of these sensors, when calibrated correctly, can save significant time compared to the previous method of manually counting microalgae cells. The mini-photobioreactor built in 2012 is shown in fig. 2 (*Senior Design Proposal*).

Figure 2 shows the Photobioreactor created last year. It incorporated sensors to monitor the microalgae growth. (Senior Design Project)

This year's project will include several objectives that build on the efforts of previous groups and a few objectives that require the design of new devices, as well. The project is intended to reach a milestone of continuous photobioeactor operation, as well as to build more resources for research at UFPR and FAMU-FSU COE to strengthen this collaborative international project.

3.0 Objectives

The main goal of this project is to satisfactorily complete, as defined by the customer, objectives 1-4 listed below and complete objective 5 only if the previous objectives have been completed. The deadline for this goal is the end of spring semester 2014. The FAMU-FSU College of Engineering and Federal University of Paraná will work together to accomplish these tasks. The objectives were either obtained from the project proposal submitted by the customer or through dialogue with the customer about the project.

The main objectives for the FALL/SPRING SEMESTERS are as follows:

1. *Grow two types of microalgae*
2. *"Design and develop two devices (units) for low cost, automatic growth media addition and biomass extraction from photobioreactors."* (*Senior Design Proposal*)
3. *"Submission of an invention disclosure in the US and a patent in Brazil of a concentration / mass flow rate sensor."* (*Senior Design Proposal*)
4. *Improve previously developed mass flow rate and concentration sensors*
5. *"Design and develop a platform (12 L airlift photobioreactor) to test such automatic units."* (*Senior Design Proposal*)

4.0 Methodology

Planning and organization will be essential to a successful international project. The FAMU-FSU College of Engineering and Federal University of Paraná teams will have to work together to achieve the objectives listed above. The overall project will be divided into two teams: the FAMU-FSU team and the UFPR team. The FAMU-FSU team consists of three mechanical engineers and a chemist. The engineering team will consist of a project leader, sensor and mechatronic team leader, and algae team leader. The chemist will work with the algae team leader to create and maintain the proper chemical compositions of the algae and food. The UFPR team consists of one FSU student and four UFPR students. At least once a week, the two teams will meet by video conference to provide updates and address relevant problems. All major design processes such as brainstorming or concept generation, as well as important group decisions will be discussed via video conference.

The first task of the FAMU-FSU team will be to grow two different types of algae. After the algae are grown, the team will make any necessary modifications to the mass flow rate and concentration sensors to improve their functionality – i.e. their modularity, mobility, and ease of use. While working on the above tasks, an invention disclosure will be filed with Florida State University. This is a disclosure that tells the University this technology may be worth patenting. The goal is to have the sensors calibrated and improved by the end of the fall semester. If this goal is accomplished, a 12L airlift Photobioreactor will be built in the spring. Dr. Ordonez is the advisor and sponsor of the FAMU-FSU team.

In Brazil, the UFPR team will first complete a patent application to Instituto Nacional da Propriedade Industrial (INPI) in Brazil for the mass flow rate and concentration sensors. The goal is to complete the patent application within the first month of the project. Next, they will be developing the algae extraction and media addition units. These units must be adaptable to all existing photobioreactor systems at FAMU-FSU COE and UFPR. The goal is to have a working prototype by the end of the fall semester in order to be tested during the spring semester. Dr. Vargas is the advisor and sponsor of the UFPR team.

5.0 Expected Results

Customer identified expected results as outlined by Ordonez and Vargas in the project proposal:

1. *"Design and construct operational units."*
2. *"Design and construct an airlift photobioreactor to test the sensors."*
3. *"Provide enough experimental data to test operation of the designed units."*
4. "It should be fully *automated."*
5. *"It should be low-cost."*
6. *"It should be for long term outdoor use."*
7. *"Units must be scalable and readily adaptable to: 12L airlift photobioeactor (to be constructed by the team), existing mini-photobioeactors (at FSU and UFPR)."*
8. *"Write an invention disclosure (FSU team) to be submitted to the USPTO by the OTT/FSU and a patent request (Brazilian team) to be submitted to the Brazilian INPI, for the concentration/mass flow rate sensor developed by the 2012/2013 team."*
9. *"Estimated Costs of Hardware, or Items Provided by Sponsor: Approx. $3000"*

Additional expected results:

1. *Have a healthy culture of microalgae maintained for testing.*

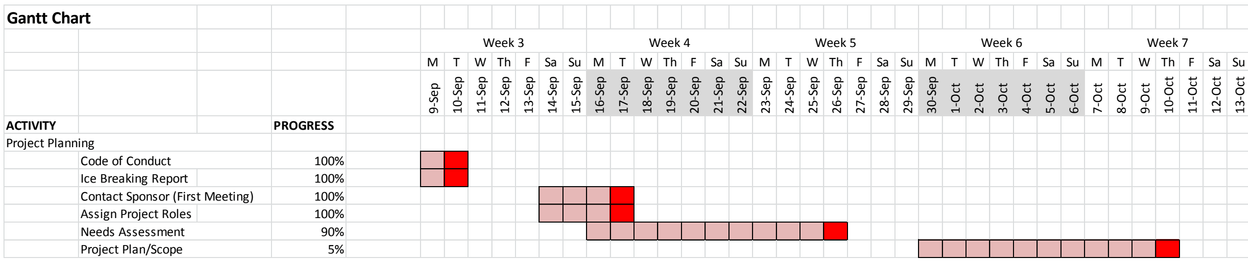
The expected result of the entire project is to have all of the components required for continuous algae-growth both developed and tested. Currently, on the full-scale photobioreactor in Brazil, algae concentration is still determined from manual counting and the entire system operates on "batch" system marked by operational stops for algae extraction, media addition, and system cleaning. By the end of the academic year, the team expects all photobioreactors at FAMU-FSU COE and at UFPR to be capable of operating continuously – where algae are extracted and media added without needing to shut down the system. The team expects significant time savings and an increase in overall rate of biomass extraction.

6.0 Constraints

The time it takes for the algae to grow is a major constraint of this project. Before any of the sensors can be calibrated, a sufficient amount of algae must be grown. This process can take up to two month and must be started right away to not have any delays. Another constraint will be communication. In an international project, it will be vital to keep communication so progress continues according to expected deadlines. Weekly video conferences will be made to keep each team up to date on what the other team is doing. Finally, our budget is a constraint. Our team was given a budget of $1,500. The project budget must stay under this value.

7.0 Gantt Chart

A Gantt chart for weeks one through seven is shown below. This is just an initial Gantt schedule and will be updated throughout the semester.



8.0 References

1) Chisti, Yusuf. *Bio Diesel from Microalgae*. N.p.: Biotechnology Advances, n.d. Print.

2) Ordonez, Juan C., and Jose Vargas. "Senior Design Proposal, 2013-2014." FSU and UFPR, n.d. Web. 26 Sept. 2013.