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Invited Paper

Novel Ocean System for High Density Mass Production of Seaweed Biomass in Korea

*Hyun Chung[1)], Nam-Gil Kim[2)], Kook-Jin Choi[3)], Hee-Chul Woo[4)]

[1)] *Department of Mechanical Engineering, KAIST, Daejeon 305-600, Korea*
[2)] *Department of Marine Biology and Aquaculture, Gyeongsang National University, Tongyeong Gyeongnam 650-160, Korea*
[3)] *Department of Mechatronics, Korea Polytechnic College, Changwon Gyeongnam 642-772, Korea*
[4)] *Department of Chemical Engineering, Pukyung National University, Busan 608-739, Korea*
[1)] *hyunny92@kaist.edu*

ABSTRACT

The scientific results of recent years have clearly demonstrated the potential of seaweed as a feedstock for biofuel manufacturing and much progress has been made in understanding molecular and physiological. However the high cost of seaweeds biomass production remains an obstacle and the much remains to be investigated further.

In this paper, we introduce a novel ocean system for high-density seaweed biomass production system, performed at Aquatic Biomass Research Center (ABRC) in Korea. The TLP type system is designed to cultivate the seaweeds in the open sea, where conventional aquaculture is practically impossible due to the severe weather conditions. The automatic seaweed planting and harvesting system has been developed in order to increase the economic feasibility of the overall system. The planting and harvesting operations are analyzed as the most labor-intensive phases across the life cycle of the seaweed cultivation, so these operations are selected primarily for the automation in order to enhance the economic feasibility.

The pilot system is now installed at open sea site near Cheong-San-do island, between Wando, Jeollanamdo and Jeju island. And the multidisciplinary efforts in building the pilot site will be discussed.

[1)] Professor, corresponding author
[2)] Professor, co-author
[3)] Professor, co-author
[4)] Professor, co-author

1. INTRODUCTION

As the global warming and global climate change has become an issue for decades. Energy industry is driving its efforts in search for a new environmentally sustainable, economically viable energy sources (Wright 2006). Carbon neutrality is one of the new concepts emerging during this effort, and now it has provided a new ground for biomass as a promising energy source.

Bio energy is defined as the whole energy that can be obtained from all the biomass from a living organism (mostly plants). At the earlier stages of biomass research, corns and crops are the main sources of the biomass, and then more abundant cellulosic biomass became more popular. Aquatic biomass research follows the previous researches and is now gaining more interests because it can utilize the vast ocean space instead of limited land space (Song et al. 2015).

The field of research focused on biofuels from seaweeds is still relatively new, as compared to more established biofuel feedstocks such as corn, sugar cane, oil palms. In addition, the aquatic nature of seaweeds makes them fundamentally different in terms of large-scale cultivation, harvest and processing. The scientific results of recent years have clearly demonstrated the potential of seaweed as a feedstock for biofuel manufacturing and much progress has been made in understanding molecular and physiological mechanisms as well as the engineering necessary for large-scale cultivation. However the high cost of seaweeds biomass production remains an obstacle and the much remains to be investigated further (Choi et al. 2014).

This research is a part of the integrated aquatic biomass research, led by Aquatic Biomass Research Center (ABRC) in Korea. The purpose of the research is to design and validate the high-density mass production system of brown-algae, and provide the test ground for future researches in ABRC to verify the aquatic biomass is technically feasible as well as economically viable energy source.

2. OFFSHORE MACROALGAE MASS PRODUDCTION SYSTEM RESEARCH

In order to provide a stable and economically feasible production of macroalgae biomass, we proposed the high-density mass production system research for a seaweed biomass. The system research consists of three parts, (1) selection of seaweeds and their seed planting methods for high-density mass production, (2) a Tension-Leg Platform (TLP) type aquaculture system, and (3) automatic seaweed planting and harvesting system.

2.1 High density production of seaweed experiments

Experimental study for high density production of seaweed biomass was carried out at three *Saccharina* culture grounds (Gijang, Tongyeong and Wando) in Korean coast from December 2010 to July 2012. After the young fronds have grown to 1-2cm in length, the seed strings are removed from the seed frame and attached to the main culture rope in one of several ways (insertion and winding of seed string). Popular method is to cut seed strings into ca. 3-4cm length which are then inserted at 30-50cm intervals into the twist of the main culture rope (long-line). In this study, seed strings are then inserted (10cm, 25cm and 50cm in interval) to or wound the main culture rope. Maximum production of *Saccharina* by the inserted interval of seed string were 80.6kg•wt•m^{-1} in Gijang, 77.8kg•wt•m^{-1} in Wando and 49.6kg•wt•m^{-1} in Tongyeong in 10cm interval. The experimental seeding alternatives are shown in Fig. 1.

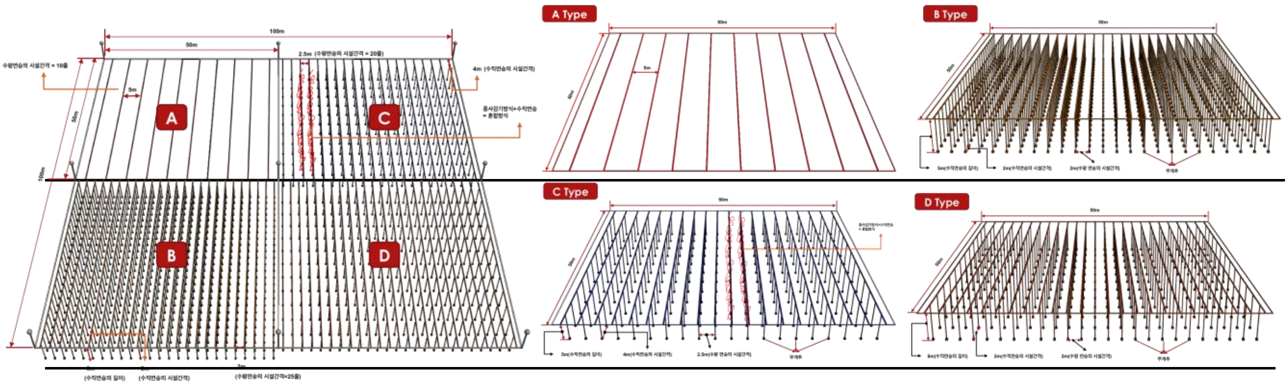
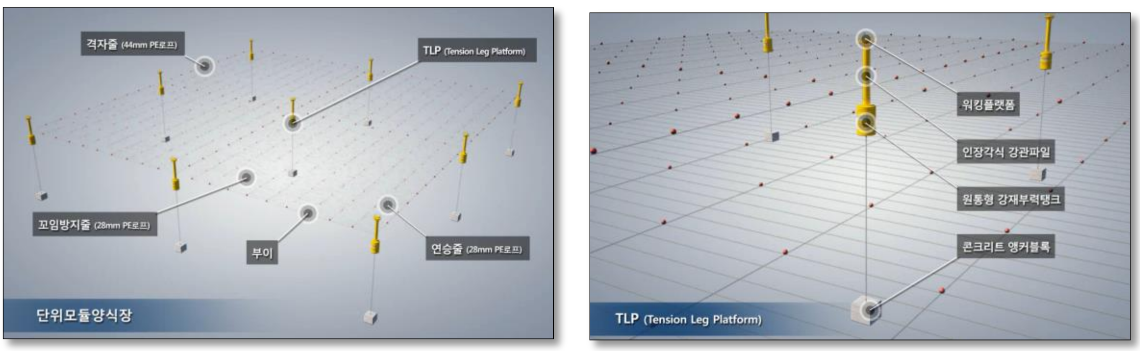


Fig. 1 Different seeding methods configurations

2.2 Tension Leg Platform (TLP) system for offshore aquaculture

A module of TLP type system is designed to cultivate the seaweeds in the open sea, where the cultivation of conventional edible seaweed, oyster and fish farms are practically impossible due to the severe weather conditions. The TLP concept is chosen because it can provide very high vertical stability at heavy seas and the mooring system can cover medium to very deep water depth. TLP has very limited horizontal restoring forces but the installation of multiple adjacent modules could provide loose horizontal restoring forces. The system is designed as a 4 ha module, which can be easily scalable to the larger area by adding multiples of modules. For real sea installation, a quarter module is installed. Fig. 2 shows one 4 ha module design.

In order to design the offshore aquaculture system, we use design rules considering the extreme condition, so that the system could survive the 50 year typhoon conditions. Once the basic design is fixed, we also performed scale model test at KAIST wave basin.



(a) overall 4ha module design (b) TLP mooring system

Fig. 2 Aquaculture system module and TLP design

2.3 Automatic seaweed planning and harvesting system

The automatic seaweed planting and harvesting system has been developed in order to increase the economic feasibility of the overall system. The planting and harvesting operations are analyzed as the most labor-intensive phases across the life cycle of the high-density seaweed cultivation, so these operations are selected primarily for the automation.

In addition to the automatic system, we also designed an remote-sensing and monitoring system, which allows the manager of the high-density biomass production system can remotely check the overall system status as well as the sea condition including salinity, sea water temperature, underwater illuminance.

3. PILOT SYSTEM INSTALLATION

The pilot system is now installed at open sea site near Cheong-San-do island, between Wando, Jeollanamdo and Jeju island. Fig. 3 shows the pilot system installed in open sea.

Fig. 3 Offshore macroalgae high-density production pilot system installed near Cheong-San-do island

4. CONCLUSIONS

The purpose of this research is to prove the technical feasibility of the offshore macroalgae high-density production as well as the raw data for the economical feasibility study. The TLP type modular aquaculture system is chosen for future mass production of the seaweeds, and variety of planting methods are being experimented in search for best planting configurations. The system is installed in real open sea and is providing the future aquatic biomass research in Korea, lead by ABRC. The short term goal of this pilot system is to provide at least 150 tons/ha of macroalgae biomass, and eventually to 300 tons/ha.

The research is an exemplary in terms of multidisciplinary collaboration, incorporating marine biologists, chemical engineers, civil engineers, mechatronics/control engineers, as well as naval architects and marine engineers. The participation of researchers from all the disciplines proves to be very successful in nurturing new ideas utilizing oceans in innovative ways.

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