DESIGN OF HARVESTING AUTOMATIC SYSTEM FOR UNDERWATER CULTIVATED LAVER

[1]BYEONG JUN KIM, [2]KYOO JAE SHIN

[1,2]Dept. of Creative ICT Engineering, Busan University of Foreign Studies,
Geumsaem-ro 485beon-gil, Geumjeng-gu, Busan 46234
Email: [1]kbj@bufs.ac.kr, [2]kyoojae@bufs.ac.kr

Abstract - In the South Korea, edible laver cultivation has grown into an important maritime industry in the coastal area. Laver producing is a very difficult and dangerous task because it is done at sea. In addition, acid treatment is performed to remove weeds from the laver, which causes marine pollution. In this paper, we had proposed an automatic harvesting unit and acid processing system for laver harvesting. This automated system consists of a design of boats with hydraulic, cylindrical and linear actuators, and the acid treatment system consists of microprocessor, pump and pH sensors which can be used to maintain a certain level of acidic character of the water. The proposed system prototypes have been implemented and met with the performance to achieve even higher levels.

Index terms - Marine industry, Water laver, Automatic harvesting, Acidic processing system, Laver cultivation, Harvesting robot, Laver farming, Activation processing, Processing control

I. INTRODUCTION

Since seafood has been used in many nutritious and many asian cuisines in Korea, seafood has become an important marine industry not only in coastal areas but also in fisheries[1]. Laver is traditionally consumed in Asia, especially in Korea, Japan and China, but it is sometimes consumed in other parts of the world. However, in recent years the demand for marine laver has increased while the popularity of oriental cuisine in western countries has increased[2]. Laver is characterized by high fiber and minerals, low fat content and, in some cases, relatively high protein content. The intake of seaweeds, including steaming, increases dietary fiber intake and reduces the incidence of chronic diseases such as diabetes, obesity, heart disease and cancer[3]. The traditional laver style is produced on the sea surface as shown in Fig. 1(a), which it had taken a water laver using a rotary machine by placing laver net on the boat. The dried laver is dried as shown in Fig.1(b) and is produced as edible laver that we had enjoyed.



(a)



(b)

Figure 1: The traditional underwater laver. (a)Harvesting laver work, (b) Laver food

Laver cultivation is every year starting from October and ending April of next year. The cultivation nets are placed at approximately 10–20 cm below the sea surface with supporting floats with laver spores attached to the nets, grow during winter, and the grown laver is harvested in next April.

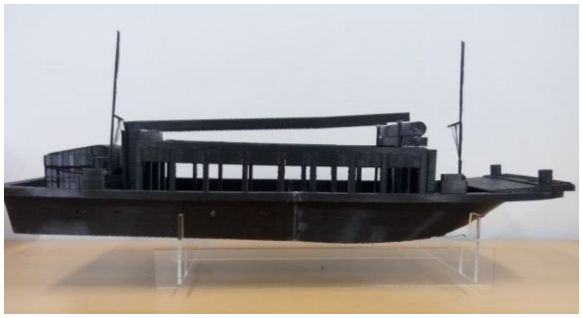


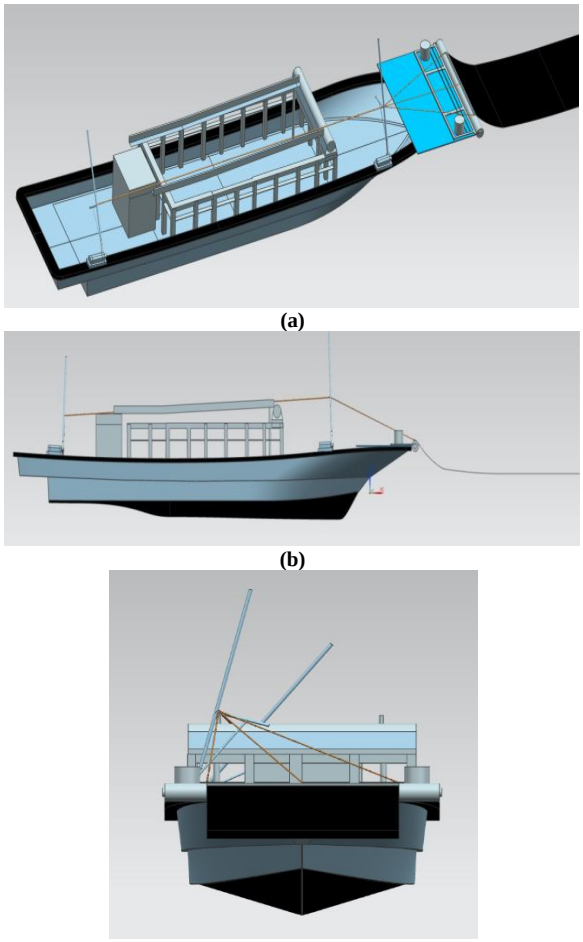
Figure 2: Prototype of the proposed harvesting system

Through, this process, the nets are sometimes placed above the sea surface to promote photosynthesis. When the nets are placed underwater, it is difficult work because of weather condition is not good due to wind and wave it can be produced not good floor which harms the human. Therefore, the cultivation area should be installed the laver cultivation nets[4, 5, 6] in under sea surface. The prototype of the proposed harvesting system is shown in Fig.2, which it is consist of automatic harvesting and acidic processing system.

II. DESING OF AUTOMATIC HARVESTING SYSTEM FOR LAVER

The design of the automatic harvesting system as shown in the Fig.3. This system consists of boat, roller, control valves, hydraulic actuators, and ropes. Initially the rope is moving through the support of the hydraulic actuators[7]. When hydraulic actuator connected with the two lifting bars. These two are

fixed at the front and rear ends of the boat to pull the rope on the boat through the support of the roller. After getting the rope on the boat, the laver is cutting down into the bottom of the boat. After collecting the laver, the rope will get outside of the boat, the process will be begun at the front end bar and ends with the rear-end bar. This process runs continuously until the laver collecting finished.



(a) **(b)** **(c)**

Figure 3: Design of automatic harvesting system, (a) 3D view, (b) Side view, (c) Front view

The mathematical equations of the lifting bar as follows[8, 9] is that the proportional integral (PI) controller can be expressed as in (1).

$$PI = K_p + \frac{K_I}{s} \qquad (1)$$

Where, K_p is proportional gain, K_I is integral gain and PI is proportional integral (PI) controller. The force balance equation for the lifting bar 1is used for opposing a load force F_L in the z direction expressed as in (2).

$$F_L = A\left(P_A - P_B\right) \qquad (2)$$

Where, F_L is load force, A is the area of the piston, P_A is pressure level A, and P_B is pressure level B. The pressure expressing equations at level P_A and level P_B as in (3) and (4).

$$P_A = \frac{K_q}{K_c} x_m - \frac{A}{2K_c} \dot{z}_{out} + P_{s/2} \qquad (3)$$

$$P_B = -\frac{K_q}{K_c} x_m + \frac{A}{2K_c} \dot{z}_{out} + P_{s/2} \qquad (4)$$

Where, P_A Pressure level A, P_B Pressure level B, K_q is the flow gain, K_c is pressure flow coefficient, x_m is displacement, and p_s supply pressure.
The ideal actuator where force and volume efficiencies are one as expressed in (5).

$$F_L = 2\frac{Ak_q}{K_c} x_m - \frac{2A^2}{K_c} \dot{z}_{out} \qquad (5)$$

Where, F_L is load force, K_q is the flow gain, A is the area of the actuator piston, K_c is pressure flow coefficient, x_m is displacement, and p_s supply pressure. The transfer function of the lifting bar expressed as in (6).

$$\theta_{out} = \frac{K_r K_q \left(K_p s + K_I\right)}{s^2 A_m - \left(K_p s + K_I\right)\left(K_r K_q K_f\right)} \qquad (6)$$

Where, K_r is control valve gain, K_q is the flow gain, K_p is the proportional gain, K_I is the intergral gain, A_m is the area of main spool and K_f is feed back gain.

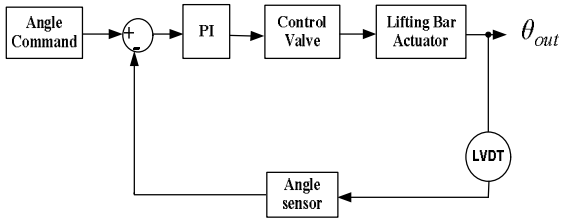


Figure 4: The Block diagram of the lifting bar.

The block diagram of the lifting bar as shown in Fig.4. It consists of PI controller, control valve, lifting bar linear actuator, and LVDT with feedback sensor. When user define the command through the algorithm, it gives to the PI controller which is control to adjustable flow to control valve to lift he lifting bar which is a linear actuator is an actuator that creates motion in a straight line, in contrast to the circular motion of a conventional electric motor.
Linear actuators are used in machine tools and industrial machinery, in computer peripherals such as disk drives and printers, in valves and dampers, and in many other places where linear motion is required. Hydraulic or pneumatic cylinders inherently produce linear motion. Many other mechanisms are used to generate linear motion from a rotating motor. The lifting bar output will feedback by the linear variable differential transformer (LVDT) (also called linear variable displacement transformer, linear variable displacement transducer, or simply differential transformer) is a type of electrical transformer used for measuring linear displacement (position).

The linear variable differential transformer has three solenoidal coils placed end-to-end around a tube. The center coil is the primary, and the two outer coils are the top and bottom secondary. A cylindrical ferromagnetic core, attached to the object whose position is to be measured, slides along the axis of the tube. An alternating current drives the primary and causes a voltage to be induced in each secondary proportional to the length of the core linking to the secondary. The frequency is usually in the range 1 to 10 kHz. Finally, if any error rises, it will correct and give to the valve to lift the bar. The flow gain can be expressed as shown in Eq. (7).

$$K_q = hc_d \sqrt{\frac{2}{\rho} P_0} \qquad (7)$$

Where, K_q is the flow gain, h is the transducer gain, c_d is the discharge coefficient, ρ is the fluid density, and P_0 is the orifice constant related to pressure variable.

The pressure flow coefficient can be expressed as shown in Eq. (8).

$$K_c = \frac{uhc_d}{\sqrt{2\rho P_0}} \qquad (8)$$

Where, u is the fixed under-lapped dimension, K_c is pressure flow coefficient, h is the transducer gain, c_d is the discharge coefficient, ρ is the fluid density, and P_0 is the orifice constant related to pressure variable.

At the pump output, the flow is split between leakage and flow to the control valve.

$$Q = q_{12} + q_{1ex} \qquad (9)$$

Where, Q = pump flow, q_{12} = control valve flow.

$$q_{1ex} = C_2 . p_1 \qquad (10)$$

Where, q_{1ex} = leakage, C_2 = flow coefficient, P_1 = pump pressure.

The transfer function of the hydraulic actuator is expressed as in Eq. (11).

$$\frac{\omega_{out}}{\omega_{desired}} = \frac{2\frac{AK_q}{K_c}h}{K_f\left(1+T_c s\right)\left(Js^2 + \frac{2A^2}{K_c}s\right) + 2hL\frac{AK_q}{K_c}} \qquad (11)$$

where $T_c = \frac{A_m}{K_q K_p K_f K_r}$, A is the area of actuator

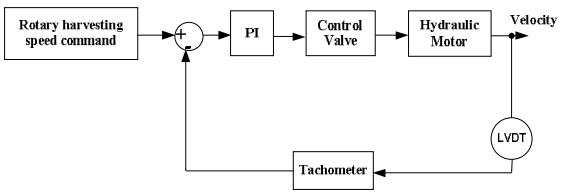


Figure 5: The Block diagram of the hydraulic motor.

the piston, K_q is the flow gain, K_c is pressure flow coefficient, h is the transducer gain, T_c is the constant, K_I is the intergral gain, J is the moment of inertia, h is the transducer gain, L is the load, and K_f is feedback transducer gain. The block diagram of the hydraulic motor actuator as shown in Fig.5. The block consists of rotary harvesting speed comm- and, PI controller, control valve, hydraulic motor, LVDT, and tachometer. The transfer function expressed as in Eq. (11) which is related to the velocity fedback by tachometer which is an instrument mea-suring the rotation speed of a shaft, as in a machine. The Hydraulic actuators or hydraulic cylinders typically involve a hollow cylinder having a piston inserted in it. An unbalanced pressure applied to the piston generates force that can move an external object. Since liquids are nearly incompressible, a hydraulic cylinder can provide controlled precise linear displa cement of the piston. The displacement is only along the axis of the piston. Typically hydraulic actuator is a device controlled by a hydraulic pump.

Fig.6 is The Block diagram of the Cylindrical actuator that provide controlled precise linear displa cement of the piston. The displacement is only along the axis of the piston. Typically hydraulic actuator is a device controlled by a hydraulic pump.

$$\frac{\theta_{out}}{\theta_{desired}} = \frac{2\frac{AK_q}{K_c}h}{K_f\left(1+T_c s\right)\left(Ms^2 + \left(D + \frac{2A^2}{K_c}\right)s + K_L\right) + 2h\frac{AK_q}{K_c}} \qquad (12)$$

where A is the area of the piston, K_q is the flow gain, K_c is pressure flow coefficient, h is the transducer gain, T_c is the constant, K_I is the integral gain, h is the transducer gain, and K_f is feedback transducer gain.

The block diagram of the hydraulic motor actuator as shown in Fig.6. The block consists of angle command, PI controller, hydraulic controller, cylindrical actuator, LVDT, and angle sensor. The transfer function of the cylindrical actuator is expressed as in Eq. (12). The hydraulic controller which is a liquid pipeline-pressure controllers. A device that uses a liquid control medium to provide an output signal, which is a function of an input error signal. Pneumatic actuators, or pneumatic cylinders, are similar to hydraulic actuators except they use compressed gas to generate force instead of a liquid[10].

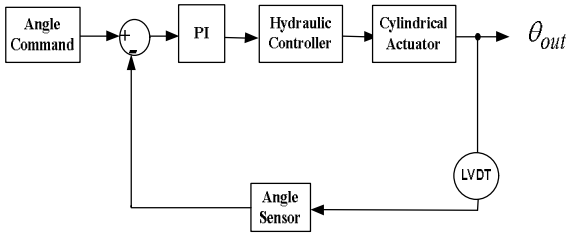


Figure 6: The Block diagram of the cylindrical actuator.

They work similarly to a piston in which air is pumped inside a chamber and pushed out of the other side of the chamber. Air actuators are not necessarily used for heavy duty machinery and instances where large amounts of weight are present. One of the reasons pneumatic linear actuators are preferred to other types is the fact that the power source is simply an air compressor. Because air is the input source, pneumatic actuators are able to be used in many places of mechanical activity. The downside is, most air compressors are large, bulky, and loud. They are hard to transport to other areas once installed. Pneumatic linear actuators are likely to leak and this makes them less efficient than mechanical linear actuators. The output signal which is fedback by the LVDT through the angle sensor.

III. DESIGN OF ACID PROCESSING CONTROL SYSTEM



Figure 7: The Block diagram of the cylindrical actuator

The prototype of the Activation processing equipment is shown in Fig.7. The processing is consists of fluid tank, water inflow and out flow tanks. In the fluid tank the fluid will mix with the sea water.

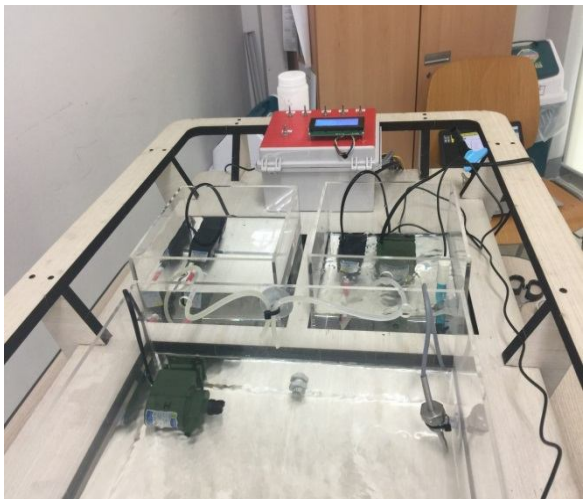


Figure 8: Acid Processing Control system.

In the fluid tank the fluid will mix with the sea water. In the mixer tank, seawater, and organic acid will be mixed by pump into the tank through the ventury for immersion time and concentration. In this tank, the pH level will be measured through the pH sensor. If the pH of water will be high in the tank, the water will be pump out and maintains the constant equillibrium of the water. The pH and, salinity measurement device and display

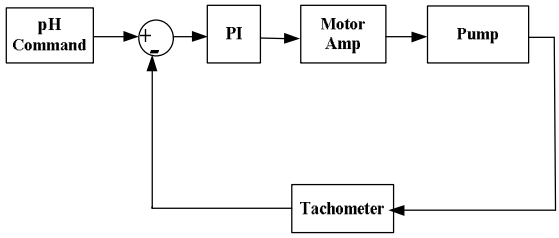


Figure 9: The block diagram of Acid Control System.

The block diagram of the Organic Acid Treatment System as shown in Fig.8. It consists of pH command, PI controller, motor amplifier, pump, and tachometer. The transfer function of the organic acid treatment system expressed as in Eq. (13). This system maintains the constant pH level of the water which is controlled by the pump.The pump works due to the pH command, if the pH of the water is high or low, the water will pump into the tank to maintain the certain pH level of the water.

$$output = \frac{\left(K_p s k_m + K_I K_m\right)\left(q_{12} + q_{1ex}\right)}{1 + \left(K_p s k_m + K_I K_m\right)\left(q_{12} + q_{1ex}\right) k_t} \qquad (13)$$

Where, K_p is the proportional gain, K_m is the motor amplifier gain, K_I is the proportional gain, q_{12} = control valve flow, q_{1ex} is leakage, K_t is feedback transducer gain.

IV. EXPERIMENT RESULTS

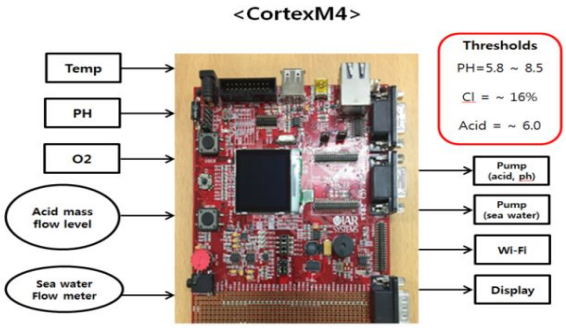


Figure 10: The control processor using Cortex M4.

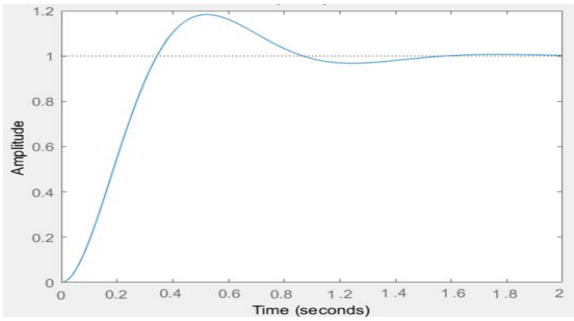


Figure 11: The simulation results of the hydraulic actuator.

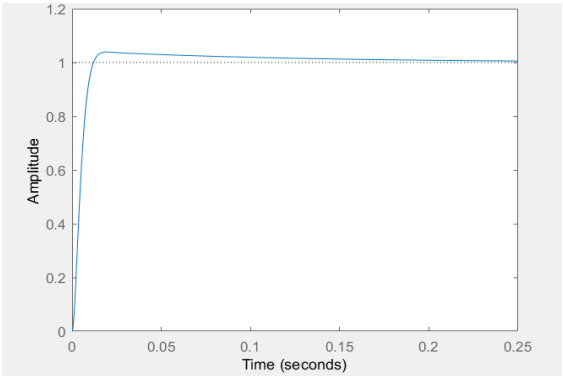


Figure 12: The simulation results of the cylindrical actuator.

The Monitoring system using Cortex M4 is shown in Fig.10. It consists of pH, Cl, acid, hydraulic motor, cylindrical actuators, pumps, acid mass flow level meter, and sea water flow meters are connected to the micom which is used as cortex m4 to control the total system and to monitor the level of pH, chlorine, acid, sea water flow meter according to data of the sensors. The range threshold values of the pH is 5.8 to 8.5, the percentage of the chlorine is to maintain the sustainable conditon at 16%, and finally the acid which is maintains at 6[11].The simulation analysis of the lifting bars such as lifting bar1 and lifting bar2 is shown in the Fig.11. When the lifting bars are lifting the system stable time is very fast. The simulation analysis of the hydraulic actuator is shown in Fig.11. It shows on the x-axis taken as time and on the y-axis taken as amplitude. It is the pressure flow analysis while moving the hydraulic actuator. The simulation analysis of the cylindrical actuator is shown in Fig.12. It is the analysis of the cylinder while moving inside and outside.The simulation results of the system has been satisfied.

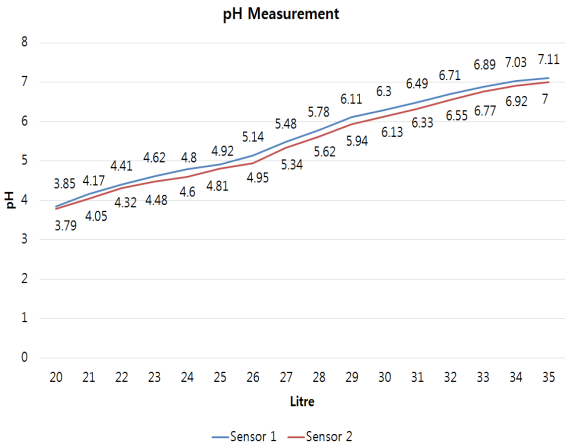


Figure 13: The experimental results of acidic processing system.

The experimental results of acidic processing system is shown in Fig.13.This graph shows that after Water laver is picked up, by using the water treatment device to make acceptable pH range of 5.8 ~ 8.5. It is an experiment to see the ratio of how much acid and water are used to determine with respective to acid: water capacity

In the experiment, we make the solution mixed with fresh water and pH 7 level of water up to 1L to maintain the constant pH in the 20L water tank.

As a result, it was found that the ratio of organic acid: tap water in the range of 26L ~ 35L is suitable for seawater tolerance (7.4 ~ 8.4).

CONCLUSION

In the conclusion, in Japan and other Asian countries laver cultivation has been an important marine industry in coastal areas as well as fishery because laver is nutrient-rich food and has been used in many Asian cuisines. Laver is characterized by high concentrations of fiber and minerals, a low fat content, and, in some cases, relatively high protein levels. So that, the automatic harvesting and acidic processing system for underwater laver cultivation has proposed. This automatic system consists of design of the boat with hydraulic, cylindrical, and linear actuators, and also acidic processing system consists of sensors which are used to maintain the certain level of the acidic nature of the water. The system prototype has implemented and satisfied by the performance to realize the further level.

ACKNOWLEDGEMENT

This project is supported by Korea Institute of Marine Science & Technology Promotion for realization “Development of water laver automatic harvesting and acid processing unit”.(PJT200942)

REFERENCES

[1] Mitsunobu Sugimoto and Kazuo Ouchi, “Extraction of Laver Cultivation Area Using SAR Dual Polarization Data” PIERS Proceedings, Moscow, Russia, pp.952-956, 2012.

[2] Berna Kılınç, Semra Cirik, Gamze Turan, Hatice Tekogul and Edis Koru, “Seaweeds for Food and Industrial Applications” Additional information is available at the end of the chapter, http://dx.doi.org/10.5772/53172 , pp.735-748, 2013.

[3] Bocanegra A, Bastida S, Benedi J, Rodenas S, Sanchez-Muniz FJ, “Characterics and nutritional and cardiovascular-health properties of seaweeds”, JMed Food, pp. 236-258, 2009.

[4] Cloude, S. R. and E. Pottier, “An entropy based classification scheme for land applications of polarimetric SAR”, IEEE Trans. Geosci. Remote Sens., Vol. 35, No. 1, pp. 68–78, 1997.

[5] S. R. Cloude and E. Pottier, “A review of target decomposition theorems in radar polarimetry”, IEEE Trans. Geosci. Remote Sens., vol. 34, no. 2pp. 498–518, Mar, 1996.

[6] S. R. Cloude and E. Pottier, “An entropy based classification scheme for land applications of polarimetric SAR”, IEEE Trans. Geosci. Remote Sens”, vol. 35, no. 1, pp. 68–78, 1997.

[7] Manuel A. Avila, Alexander G. Loukianov and Edgar N. Sanchez, “Electro-Hydraulic Actuator Trajectory Tracking”, Boston, Massachusetts, pp. 2603-2608, 2004.

[8] Y. Yamaguchi, T. Moriyama, M. Ishido, and H. Yamada, “Fourcomponent scattering model for polarimetric SAR

image decomposition", IEEE Trans. Geosci. Remote Sens., vol. 43, no. 8, pp. 1699–1706, 2005.

[9] Farid Golnaraghi and Benjamin C.Kuo, "Automatic control systems", John wiley &sons publications", 9 th edition, pp.605-610, 2010.

[10] Byeong Jun Kim and Kyoo Jae Shin, "Design of Fully Automatic Vessel for Water Laver Harvesting System", UAC International September Conference in Bangkok, 2017.

[11] Byeong Jun Kim, Suk Chil Kim, Bo Hyun Cho and Kyoo Jae Shin, "Development of automatic harvesting and acidic processing system for under water laver cultivation", International Journal of Current Research, Vol. 9, Issue, 08, pp.55659-55664, August, 2017.

★★★