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RESEARCH ARTICLE

DEVELOPMENT OF AUTOMATIC HARVESTINGANDACIDIC PROCESSING SYSTEM FOR UNDER WATER LAVER CULTIVATION

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ABSTRACT

North-East asian countries, laver cultivation has been an important marine industry in coastal areas as well as fishery because laver (Porphyra) is nutrient-rich food and has been used in many Asian cuisines. However, laver cultivation is vulnerable to natural disasters such as typhoons and tsunamis. If those disasters hit laver cultivation area, laver cultivation structures would be devastated and scattered around the coast. Laver is characterized by high concentrations of fiber and minerals, a low fat content, and, in some cases, relatively high protein levels. Consumption of seaweeds, including laver, increases the intake of dietary fiber and lowers the occurrence of some chronic diseases such as diabetes, obesity, heart disease, and cancer. In this paper, 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.

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INTRODUCTION

In Japan and other Asian countries, laver cultivation has been an important marine industry in coastal areas as well as fishery because laver (Porphyra) is nutrient-rich food and has been used in many Asian cuisines. However, laver cultivation is vulnerable to natural disasters such as typhoons and tsunamis. If those disasters hit laver cultivation area, laver cultivation structures would be devastated and scattered around the coast. This will affect not only owners of the laver cultivation structures but also the free passage of ships around the area. Laver (Porphyra tenera) is traditionally consumed in Asia, particularly in Korea, Japan, and China, but is only occasionally consumed in other parts of the world. However, the increasing popularity of orie-ntal cuisine in Western countries in recent years has increased the demand for this marine vegetable. Laver is characterized by high concentrations of fiber and minerals, a low fat content, and, in some cases, relatively high protein levels. Consumption of seaweeds, including laver, increases the intake of dietary fiber and lowers the occurrence of some chronic diseases such as diabetes, obesity, heart disease, and cancer (Bocanegra *et al.*, 2009).

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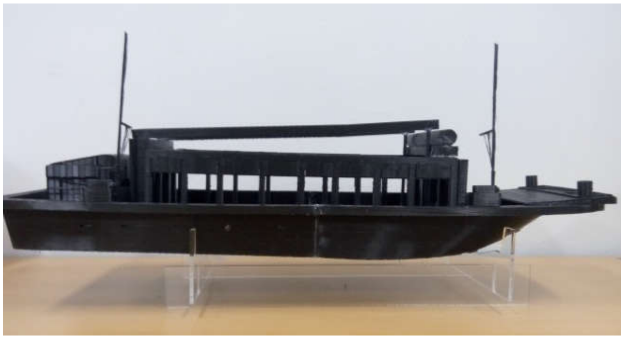
Recent studies have re- ported that seaweed extracts have strong antioxidant properties. Red seaweed, including laver, is considered as a rich source of antioxidants, such as polyphenols, phlorotannins, and fucoxanthin. In the traditional laver farming there are used in the two main cultivation methods. The traditional "racks" method used for high quality laver that is similar to naturally grown laver, and the "floating rafts" method used for mass production. The traditonal water laver cultivation as shown in Fig.1.Therefore, monitoring laver cultivation area is important. Now way days, Synthetic aper- ture radar (SAR) has been proven to be one of the most useful sensors and therefore used in a variety of areas because of its all-weather and day-and-night observation capabilities with high resolution (Mitsunobu *et al.*, 2012). In our test site of laver cultivation, every year starting from October, 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. 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 slipy floor which harms the human. Therefore, the cultivation area should have smoother sea surface compared with the area without laver cultivation nets (background area), and this difference in roughness can appear in acquired SAR data (Cloude *et al*., 1997). In recent years, polarimetric synthetic aperture radar (PolSAR) has attracted much attention in various fields of Earth science in comparison with single-polarization SAR, for its increased accuracy in image classification and analyses based on, for example, scattering decomposition and eigen value analyses (S. R. Cloude *et al*., 1996, A. Freeman *et al*., 1998, U. Benz *et al.,* 2001). In order to harvest the laver the new system is proposing to realize it. This system consists of automatic harvesting and acidic processing system. The prototype of the proposed harvesting system is shown in Fig.2.

Fig.1. The traditional underwater cultivation system



(a)

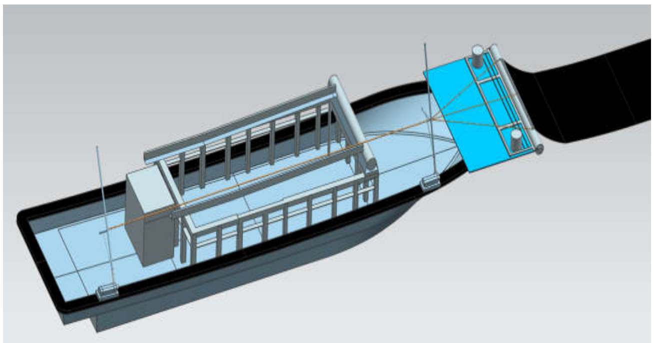
(b)

Fig. 2. Prototype of the proposed automatic harvesting system, (a) side view, (b) top view

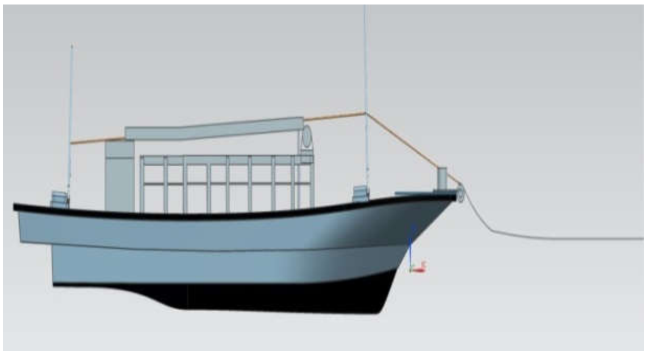
Design ofautomatic harvestingsystem for laver

The design of the Automatic Harvesitng system as shown in the Fig. 3. This system consists of boat, roller, control valaves, hydraulic actuators, and ropes. Initially the rope is moving through the support of the hydraulic actuators. Whin 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.

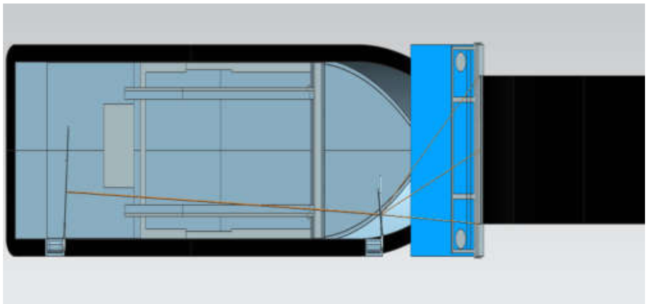
After collecting the laver, the rope will get outside of the boat, the process will be begun at the front end bar and ends with the rearend bar. This process runs continueously until the laver collecting finished.



(a)



(b)



(c)

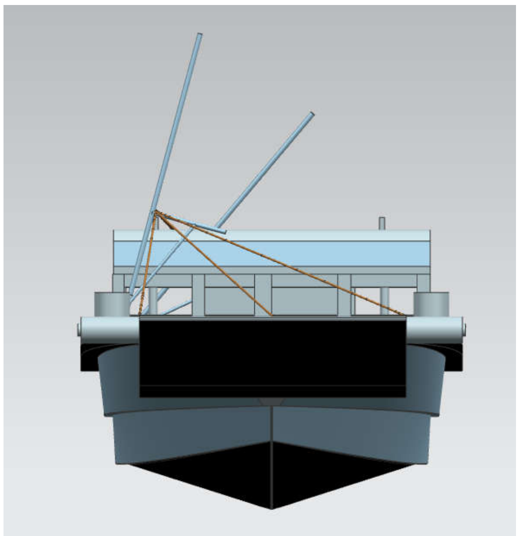


Fig. 3. Design of automatic harvesting system, (a) 3D view, (b) Side view, (c)Top view, (d)Front view

The mathematical equations of the lifting bar as follows (Yamaguchi., 2005, Farid *et al.,*2010).The proportional integral (PI) controller can be expressed as in (1).

$$PI = K_p + \frac{K_I}{s} \quad \text{....................(1)}$$

where $K_p$is proportional gain, K_I Intergral 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).

$$F_L = A\left(P_A - P_B\right) \quad \text{......................(2)}$$

where F_L is load force, A is the area of the piston, P_A Pressure level A, and P_B Pressure level B.

The pressure expressing equations at level $P_A$and level $P_B$as in (3) and (4).

$$P_A = \frac{K_q}{K_c} x_m - \frac{A}{2K_c} \dot{z}_{out} + P_s/_2 \quad \text{..................(3)}$$

$$P_B = -\frac{K_q}{K_c} x_m + \frac{A}{2K_c} \dot{z}_{out} + P_s/_2 \quad \text{..........(4)}$$

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).

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

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 thelifting bar expressed as in (6).

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

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.

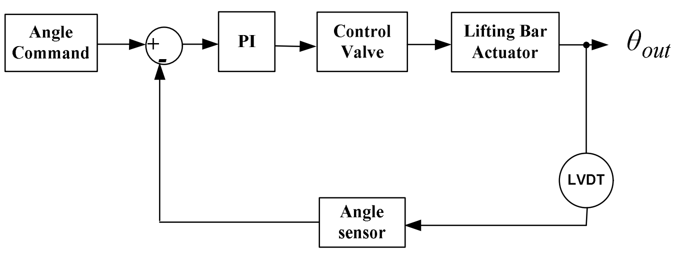


Fig. 4. The Block diagram of the lifting bar

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 feed back 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 con-ventional 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 elec- trical 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 secondaries. Acylindrical ferro- magnetic 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 lif the lifting bar. The flow gain can be expressed as shown in (7).

$$K_q = hc_d \sqrt{\frac{2}{\rho} P_0} \quad \text{.........................(7)}$$

where K_q is the flow gain, h is the transducer gain, $c_d$is the discharge coefficient, ρ is the fluid density,andP_0 is the orifice constant related to pressure variable.

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

$$K_c = \frac{uhc_d}{\sqrt{2\rho P_0}} \quad \text{...................(8)}$$

where u is the fixed underlapped 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.

$$Q = q_{12} + q_{1ex} \quad \text{...................(9)}$$

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

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

whereq_{1ex} = leakage, C_2 = flow coefficient, P_1 = pump pressure. The transfer function of the hydraulic actuator is expressed as in (11).

$$\frac{\omega_{out}}{\omega_{desired}} = \frac{2\frac{AK_q}{K_c}h}{K_f\left(I + T_c s\right)\left(Js^2 + \frac{2A^2}{K_c}s\right) + 2hL\frac{AK_q}{K_c}} \quad \text{……..(11)}$$

where $T_c = \frac{A_m}{K_q K_p K_f K_r}$,A is the area of actuator the piston, K_q is the flow gain, K_c is pressure flow coefficient, h is the transducer gain, T_c is theconstant, $K_I$is the intergral gain, J is the moment of inertia, h is the transducer gain, L is the load, and K_f is feed back transducer gain.

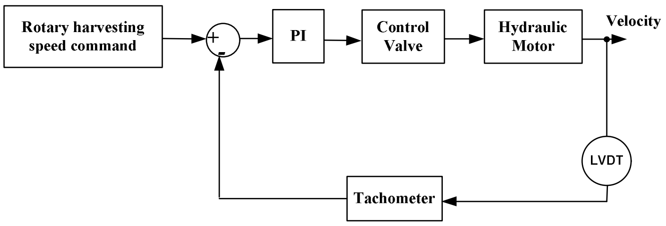


Fig. 5. The Block diagram of the hydraulic motor

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 (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, ahydraulic cylinder can.

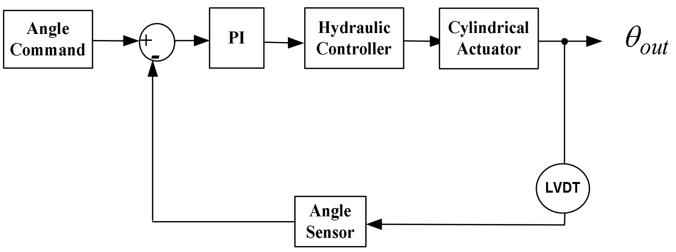


Fig. 6. The Block diagram of the Cylindrical actuator

provide controlled precise linear displacement of the piston. The displacement is only along the axis of the piston. Typically hydraulic actuator is a device controlled by a hydraulic pump.

$$\frac{\theta_{out}}{\theta_{desired}} = \frac{2\frac{AK_q}{K_c}h}{K_f\left(I + T_c s\right)\left(Ms^2 + \left(D + \frac{2A^2}{K_c}\right)s + K_L\right) + 2h\frac{AK_q}{K_c}} \quad \text{….(12)}$$

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 theconstant, $K_I$is the intergral gain, h is the transducer gain,and K_f is feed back 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 (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. 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.

Automatictesting of acidic nature of water

Activation Processing Conceptual (APC)System

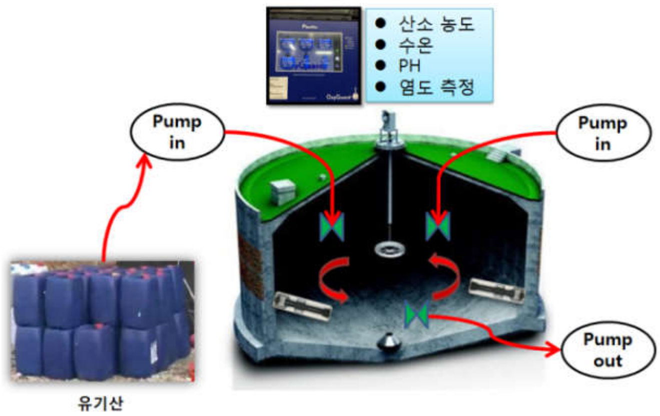


Fig. 8. Activation Processing Conceptual (APC) system

The concept of the Activation processing equipment as shown in Fig.8.The proce- ssing is consists of fluid tank, water inflow and out flow tanks. 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 venturi for immersion time and concen-tration. 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.

Concept of Organic Acid Treatment System

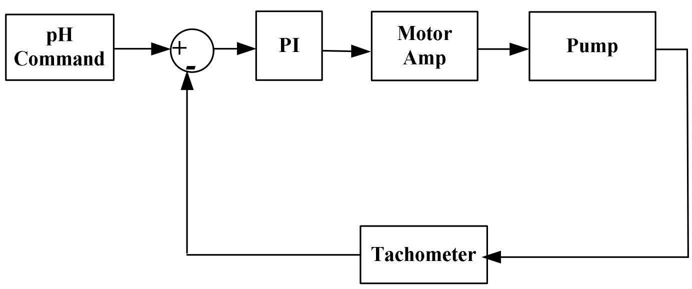


Fig. 9. The block diagram of Organic Acid Treatment System

The block diagram of the Organic Acid Treatment System as shown in Fig.9. It consists of pH command, PI controller, motor amplifier, pump, and tachometer. The transfer function of the organic acid treatment systemexpressed as in (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.

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

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} = leakage, K_t is feed back transducer gain.

Monitoring system

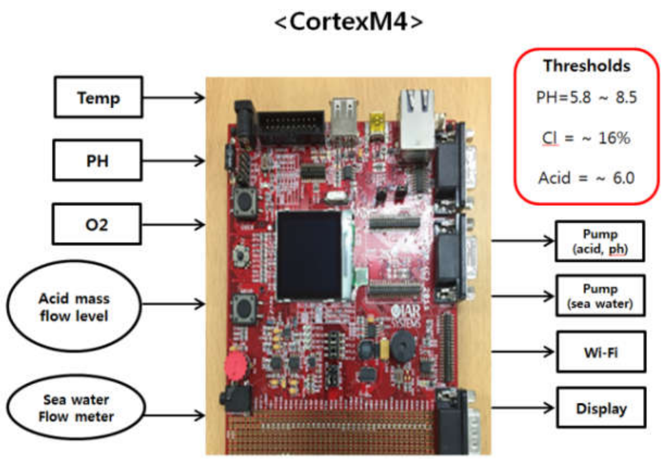


Fig. 10. The Monitoring system using Cortex M4

The Monitoring system using Cortex M4 as 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 mocom 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.

SIMULATION RESULTS

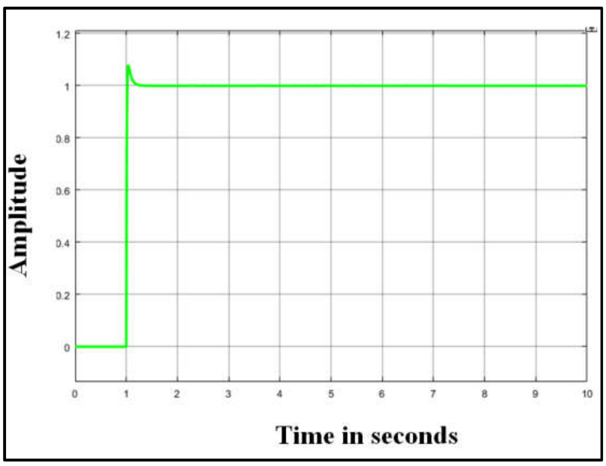


Fig.11. The simulation results of the lifting bar

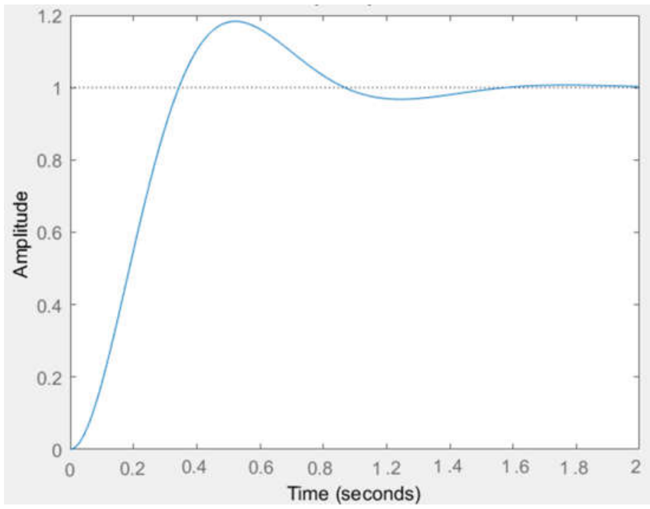


Fig. 12. The simulation results of the hydraulic actuator

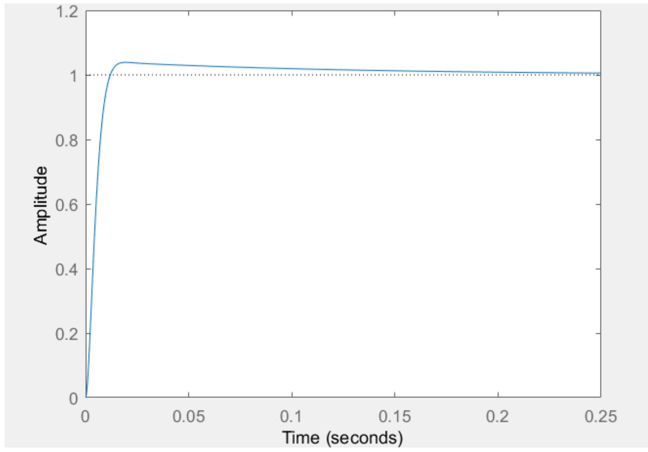


Fig. 13. The simulation results of the cylindrical actuator

The simulation analysis of the lifting bars such as lifting bar1 and lifting bar2 as 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.12. 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.13. It is the analysis of the cylinder while moving inside and outside. The simulation results of the system has been satisfied.

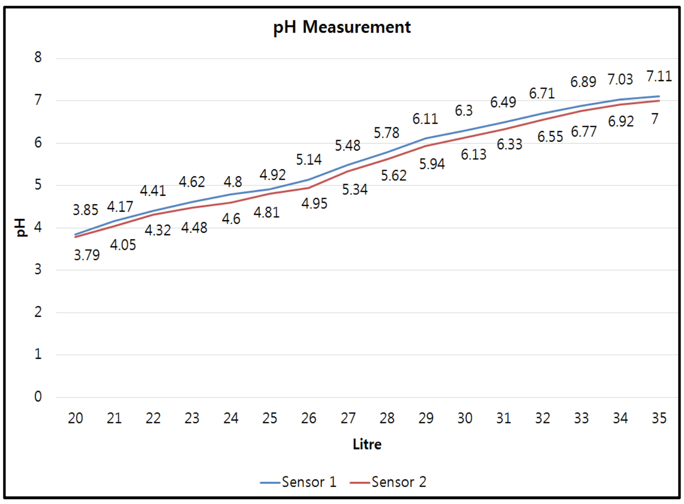


Fig. 14. The experimental results of acidicprocessing system

The experimental results of acidicproce-ssing system is shown in Fig.14. 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 upto 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 countrieslaver cultivation has been an important marine industry in coastal areas as well as fishery because laver (Porphyra) 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, relati-vely high protein levels. So that, the auto- matic harvesting and acidic processing system for underwater laver cultivation has proposed. This automatic system consists of design of the boat with hydraulic, cylin-drical, 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.

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