International Journal of
Science and Engineering Investigations vol. 4, issue 46, November 2015
ISSN: 2251-8843

Separation Characteristics of Dissolved Gases from Water using a Portable Separation System with Hollow Fiber Membrane Modules

Pil Woo Heo
Korea Institute of Machinery and Materials
(pwheo@kimm.re.kr)

Abstract**-**If dissolved oxygen included in water is effectively used, an underwater breathing device for a human is possible. But because concentration of dissolved oxygen is low, the system with large surface area is needed. So it's important to increase the performance of the portable system and to decrease the size of one.

In this study, a portable breathing device which uses under water is presented. This system composes of a water pump, filters, hollow fiber membrane modules and a vacuum pump. Separation of dissolved gases using hollow fiber module and vacuum pump is characterized. The amounts of dissolved gases separated from water were measured. The composition of oxygen contained in separated gases was measured. Constant amounts of separated gases including oxygen were measured during 50 min. These results will be applied for the development of underwater breathing device using dissolved oxygen.

Keywords**-** *Separation, portable, hollow fiber, dissolved gases.*

I. INTRODUCTION

Portable separation technology of dissolved gases can be used for various applications under water. Separation characteristics of dissolved gases using a portable device with a variable vacuum pump were represented [1]. The amounts of separation of dissolved gases were increased with vacuum state.

Generally we need air tank including oxygen which is compressed using air in order to breathe under water. This air tank is used under water during limited time. There is some oxygen under water, so a fish can breathe under water using gills which use dissolved oxygen. If we use a device which use dissolved oxygen like a fish, we can survive under water.

Minimization of high performance power source is important for portable applications. Pikul et al. showed lithium ion micro battery of 2,000 times better than previous micro battery [2]. This battery optimized ion and electronic transport for high power generation. This technology is very efficient for the development of portable devices.

Pendergast et al. represented rechargeable lithium ion battery for underwater applications [3]. Proper temperature range (-20 ~ 60 ℃) was kept in the battery. The possibility of application under 305 m seawater was represented.

We can suddenly meet a disaster in the ship and drift with life vest in the ocean. High wave can temporarily drown a human with life vest. If wave is high or a tired person meets wave, sometimes, we cannot breathe under water and can be drown. If we can get a breathing device which uses both under water and in the air, we can survive in the air using a device which extracts air and blocks water, and under water using a device which separates dissolved gases from water. Heo et al. showed the possibility of using a breathing device both in the air and under water [4]. This device is useful for the environment which changes in the air and underwater in turn.

In this study, a portable breathing device which uses under water is presented. This system composes of a water pump, filters, hollow fiber membrane modules and a vacuum pump. Separation of dissolved gases using hollow fiber module and vacuum pump is characterized. The amounts of dissolved gases separated from water were measured. The composition of oxygen contained in separated gases was measured. Constant amounts of separated gases including oxygen were measured during 50 min. These results will be applied for the development of underwater breathing device using dissolved oxygen.

II. METHODS

To separate dissolved gases containing oxygen from water, hollow fiber membrane modules with hydrophobic characteristics are used. These membrane modules block water and transport only dissolved gases.

Fig. 1 shows outline for experimental devices which include water pumps, hollow fiber membrane modules, a filter, vacuum pumps, a flow sensor, an oxygen sensor and control unit to monitor the characteristics of separated gases. The water pump supplies water into a membrane module. The vacuum pump extracts dissolved gases from water. Vapor included in dissolved gases from water is removed through filter. The battery provides a power source. The hollow fiber membrane module is made from a Liqui-Cel company and has surface area of 8.1 m^2 and maximum flow rates of 3.4 m^3/hr. Table 1 shows specifications of a hollow fiber module. The vacuum pump is N838 KNDC model from a KNF company and has delivery of 32 L/min. Table 2 shows specification of a vacuum pump. It has input voltage of 24 V to be connected to the battery. Table 3 shows specifications of a water pump and has 105 L/min of flow rates. It is from a DAEWHA company. This pump supplies water into the hollow fiber membrane module and dissolved gases are separated from water through gas lines which is positioned on the side of the membrane module. Separated gases path through the lumen side of hollow fibers and are collected to a reservoir. The flow sensor is from a OMRON company and has measurable range of 0~10 L/min. The input signal has 10.8~26.4 VDC and the output signal 1~5 VDC. The oxygen sensor is from a SENCO company and can measure 0~30 % of oxygen. Input signal has 10~30 VDC and output signal 4~20 mA. The control unit can communicate measured data to the external data acquisition system. The measured data trend is displayed in the monitor of the data acquisition system. This system has also alarms to display the dangerous state.

Fig. 2 represents a manufactured portable system and Fig. 3 shows control logic diagram for alarms. Fig. 3(a) represents flow rate of separated gases. If the flow rate is less than the predefined reference, alarm signal is monitored in the display window in the portable system. Fig. 3(b) depicts oxygen composition included in the separated gases. Two data represents the amounts of total separated gases and oxygen composition of the gases. If these values are less than predefined reference, amounts of separated gases is less than requested value and may make troubles underwater for the human.

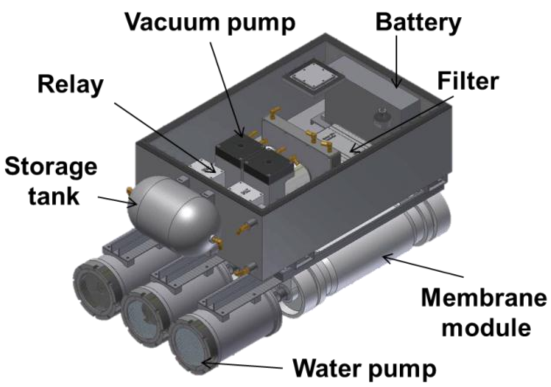


Figure 1. Outline for the portable system

TABLE I. HOLLOW FIBER CHARACTERISTICS

Name	Spec.
Material	Polypropylene
Potting materials	Epoxy
Surface area (m^2)	8.1
Porosity (%)	~25
OD/ID (μm)	300/200
Shell side volume (L)	1.26
Lumen side volume (L)	0.61
Height (mm)	512
Diameter (mm)	116.1
Maximum water flow (m^3/hr)	3.4
Pressure drop (bar) at 6.1 m^3/hr water flow	0.59

a. Sample of a Table footnote. (Table footnote)

TABLE II. VACUUM PUMP CHARACTERISTICS

Name	Spec.
Delivery at atm. pressure (L/min)	32
Pressure (bar)	0.5
Vacuum (mbar)	100
Voltage (V)	24
Current (A)	1.9
Weight (kg)	2.2

a. Sample of a Table footnote. (Table footnote)

TABLE III. WATER PUMP CHARACTERISTICS

Name	Spec.
Weight (kg)	2.3
Power (W)	160
Maximum flow (L/min)	105
Head (m)	7
Voltage (V)	24
Diameter (mm)	135
Height (mm)	245

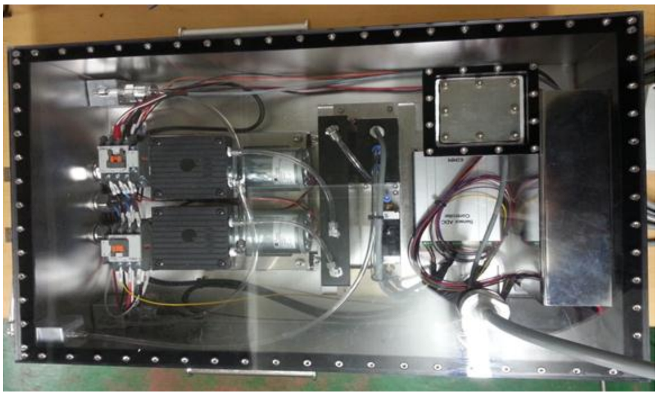
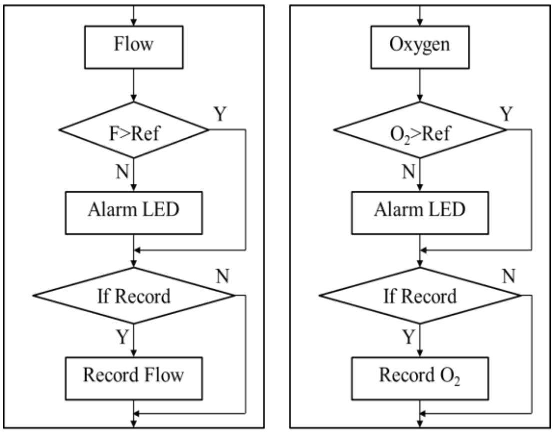


Figure 2. Manufactured portable system



(a) flow rate (b) oxygen composition

Figure 3. Control logic diagram for alarms

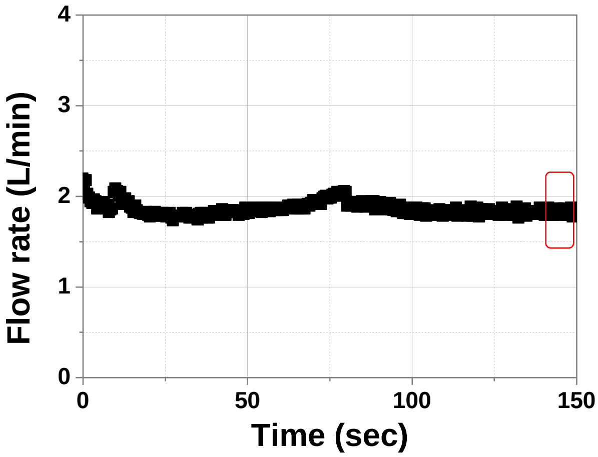


Figure 4. Separation of dissolved gases

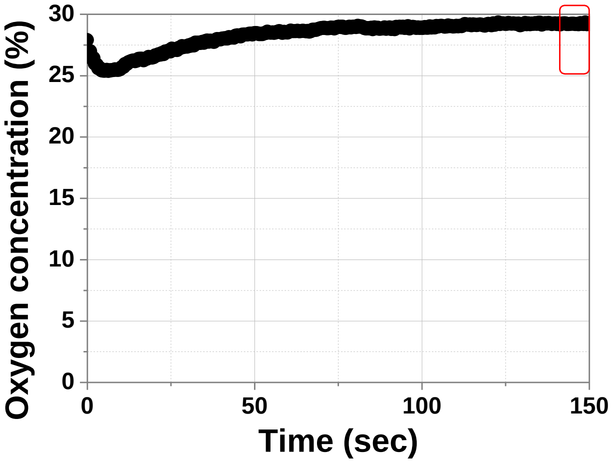


Figure 5. Oxygen concentration

III. RESULTS AND DISCUSSIONS

Each hollow fiber membrane module includes two kinds of port. One is water line which is located in the center. The other is gas line which is separated from water using a vacuum pump and is positioned on the side of the membrane module. Fig. 4 shows separation characteristics of dissolved gases using proposed system. After some fluctuation at the first, constant flow rate was kept. A red box shows area for quantitative analysis. Fig. 5 represents the amounts of oxygen included in separated dissolved gases.

Table 4 shows the amounts of separation and oxygen which is included in the separated dissolved gases. Separated gases had 1.904 L/min of flow and oxygen had 28.96%, which was more than one of oxygen in the air. If we use separated dissolved gases for underwater breathing, proper processing is needed. Table 5 shows before and after water characteristics in the view of dissolved oxygen. The composition of dissolved oxygen was decreased after the portable separation system.

Power consumption of this system was 500 W and supplying power of lithium ion battery had 480 W. This system operated under water during about 50 minutes.

TABLE IV. SEPARATION AND OXYGEN CONCENTRATION

No.	Separation (L/min)	Oxygen Concentration
1	1.9	28.99
2	1.88	28.94
3	1.89	28.95
4	1.93	29.02
5	1.87	28.98
6	1.89	28.99
7	1.93	28.90
8	1.90	28.96
9	1.91	28.88
10	1.94	28.99
Mean	1.904	28.960

TABLE V. WATER CHARACTERISTICS

Name	Spec.
DO(In)(mg/L)	9.74
DO(Out)(mg/L)	4.06
In-Out	5.68
Sep(%)	58.3
Temp(℃)	7.5

IV. CONCLUSION

In this thesis, a proposed portable separation system using 3 hollow fiber membrane modules was represented. This system has water pumps, hollow fiber membrane modules, filters, vacuum pumps, control unit, a flow sensor and an oxygen sensor. Separated gases kept relatively constant state and had 1.904 L/min of flow rates. The oxygen compositions of separated gases showed 28.96 %. Power consumption of this system was 500 W and this system could operate underwater during about 50 minutes. If enough power is supplied to this system under water, separated gases including dissolved oxygen can be used for a variety of areas during long time. Of course, some applications need more gases including oxygen, so separation system with more surface area is requested. But these results are meaningful in view of self- supplying system which uses gases containing dissolved oxygen separated from water without going underwater out.

REFERENCES

[1] P. W. Heo and I. S. Park, Separation of Dissolved Gases from Water for a Portable Underwater Breathing, World Academy of Science, Engineering and Technology, pp. 1104-1107, 2013.

[2] J. H. Pikul, H. G. Zhang, J. Cho, P. V. Braun, and W. P. King, High-power lithium ion microbatteries from interdigitated three-dimensional bicontinuous nanoporous electrodes, Nature Communications, pp. 1-5, 2013.

[3] P. W. Heo and I. S. Park, Separation of dissolved gas for breathing of a human against sudden waves using hollow fiber membranes, World Academy of Science, Engineering and Technology, pp. 1258-1261, 2012.

[4] D. R. Pendergast, E. P. DeMauro, M. Fletcher, E. Stimson and J. C. Mollendorf, A rechargeable lithium-ion battery module for underwater use, Journal of Power Sources, pp. 793-800, 2011.