한국박용기관학회지 제27권, 제6호, pp. 714~720, 2003 (ISSN 1226-9549)
Journal of the Korean Society of Marine Engineers

LiBr작동유체 중에서 가스흡수식 냉온수기의 국부부식 특성에 관한 연구

임우조† · 정기철** · 윤병두***

(원고접수일 : 2003년 6월 3일, 심사완료일 : 2003년 6월 24일)

A Study on the Characteristics of Local Corrosion for Gas Absorption Refrigeration and Hot Water Systems in LiBr-H_2O Working Fluids

Uh-Joh Lim† · Ki-Cheol Jeong** · Byoung-Du Yun***

Key words : Gas Absorption Refrigeration and Hot Water System, Local Corrosion, Dissimilar Metal Corrosion, Lithium Bromide, Heat Exchanger Tube

Abstract

Due to the electric power shortage in summer season and regulation of freon refrigerant, the application of gas absorption refrigeration and hot water systems are considerably increasing trend. But, this system consists of condenser, heat exchanger, supply pipe and radiator etc, which are easily corroded by acidity and dissolved oxygen and gases. In result, this system occurs scale attachment and corrosion damage like pitting and crevice corrosion. In this study, electrochemical polarization test of heat exchanger tubing material (copper, aluminium brass, 30% cupronickel(30% Cu-Ni)) was carried out in 60% lithium bromide solution at 95℃. As a result of polarization test, corrosion behavior by impressed potential and local corrosion, such as galvanic corrosion, pitting corrosion behavior, of tubing materials was investigated. The main results obtained are as follows : (1) The effect of pitting and crevice corrosion control of 30% cupronickel in 60% LiBr solution at 95 ℃ is very excellent. (2) Dissimilar metal corrosion of 30% cupronickel coupling to aluminium bronze is the most sensitive. (3) Current density behavior of tube materials by impressed potential is high in order of copper 〉 aluminium brass 〉 30% cupronickel.

† School of Mechanical Engineering, Pukyong University, E-mail : limuj@pknu.ac.kr, T : 051-620-1602
** Department of Gas & Refrigeration, TongMyong College
*** Graduate School, Department of Mechanical Engineering, Pukyong University

1. Introduction

The vapor compressed refrigeration system is restricted by the environmental regulation because freon refrigerant causes environmental pollution problem like an ozone layer destruction, greenhouse effect. But, the gas absorption refrigeration and hot water system recently induces water instead of freon as refrigerant, to decrease exhaustion of the atmospheric pollution substance. Also this system uses gas as power source to minimize the electric energy consumption.

Recently, working fluid of this system induces water as refrigerant and lithium bromide come in to use absorbent. But, if corrosion reaction occurs in gas absorption refrigeration and hot water system by lithium bromide, heat transfer capacity becomes low due to attachment of corrosion products at heat transfer surface. Especially, this system consists of condenser, heat exchanger, supply pipe and radiator etc, which are easily corroded by acidity and dissolved oxygen and gases. In result, scale attachment and corrosion damage like pitting and crevice corrosion to this system occur[1]-[4].

The gas absorption refrigeration and hot water system applies copper and copper alloy to tube and tube sheet of heat exchanger in order to improve heat transfer capacity and anti-corrosion. Therefore, a study on the characteristics of local corrosion for gas absorption refrigeration and hot water system in LiBr-H_2O working fluids is requested[5]-[7].

In this study, electrochemical polarization test of heat exchanger tubing material (copper, aluminum brass, 30% cupronickel (30% Cu-Ni)) was carried out in 60% lithium bromide solution at 95℃. As a result of polarization test, corrosion behavior by impressed potential and local corrosion, such as galvanic corrosion, pitting corrosion, behavior of tubing materials was investigated.

2. Test material and experimental method

2.1 Test material and specimen

Test material used in this study is copper(Cu), aluminum brass(Al-brass) and 30% cupronickel(30% Cu-Ni) which are heat exchanger tube material, and aluminum bronze is used in galvanic corrosion experiment.. Table 1, 2, 3, 4 show the chemical compositions and mechanical properties of used material.

Table 1 Chemical compositions and mechanical properties of Cu (C1220T-OL)

Chemical composition (wt %)	Cu		P
	99.97		0.03
Mechanical properties	Tensile strength (MPa)	Yield strength (MPa)	Elongation (%)
	372	-	42

Table 2 Chemical compositions and mechanical properties of Al-brass

Chemical composition (wt %)	Cu	Al	Ni	As	Pb	Fe	Zn
	77	2.1	0.6	0.04	0.05	0.05	Remainder
Mechanical properties	Tensile strength (MPa)				Elongation (%)		
	419				57		

In electrochemical polarization experiment, the effective exposure area is 1.0 cm^2 and the other area is electrically isolated by mounting. Figure 1 shows the shape and dimension of polarization test specimen.

Table 3 Chemical compositions and mechanical properties of 30% Cu-Ni

Chemical composition (wt %)	Ni	Fe	Mn	Pb	Zn	Cu
	31.0	0.7	0.6	0.05	0.5	Remainder
Mechanical properties	Tensile strength(MPa)			Elongation (%)		
	440			44		

Table 4 Chemical compositions and mechanical properties of Al-Ni bronze

Chemical composition (wt %)	Cu	Fe	Al	Mn	Ni
	81	4	9	1.5	4.5
Mechanical properties	Tensile strength (MPa)		Hardness (Hv)	Elongation (%)	
	430		100	45	

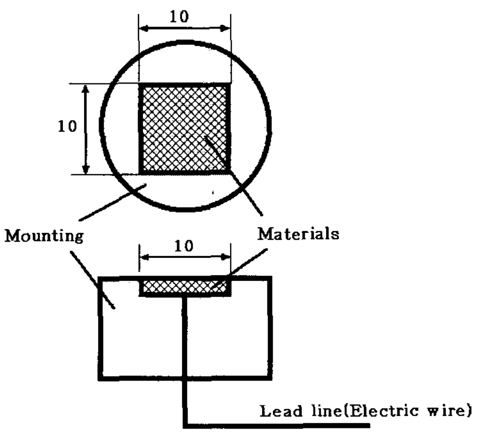
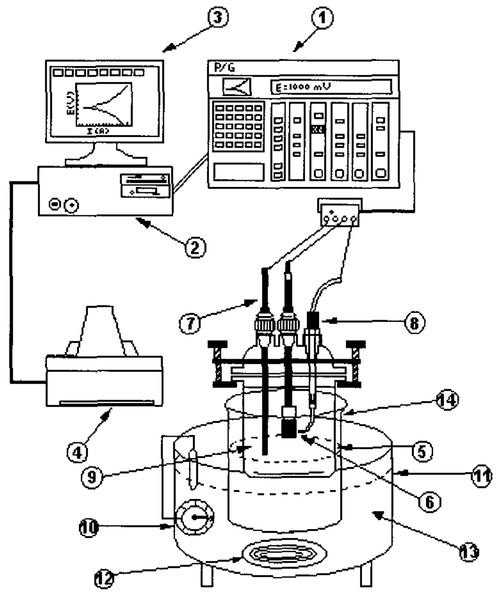


Fig. 1 Shape and dimension of polarization test specimen (unit:mm)

2.2 Experimental apparatus and method

In order to investigate local corrosion characteristics of heat exchanger tube for gas absorption refrigeration and hot water, electro-chemical polarization test device was used in this study. Also, this method can be non-destructively carried out, and test time of this method is shorter than another corrosion test.



① Potentiostat/Galvanostat ② Personal computer ③ Monitor ④ Printer ⑤ Corrosion cell ⑥ Specimen ⑦ Counter electrode ⑧ Reference electrode ⑨ Electrolyte ⑩ Temperature controller ⑪ Heater body ⑫ Heating coil ⑬ Oil bath ⑭ Heating beaker

Fig. 2 Schematic diagram of polarization test equipment

Electrochemical polarization experimental apparatus used for local corrosion test consists of M 352 potentiostat/galvanostat (EG&G co.), personal computer and printer in order to record polarization curves. Figure 2 shows the schematic diagram of electrochemical polarization test equipment.

Corrosive liquid is 60% lithium bromide

solution and is made by adding lithium bromide reagent to distilled water. Also, test temperature, which is inside temperature of regenerator, was stabilized at 95±1℃.

3. Results and Discussion

3.1 Local corrosion behavior of heat exchanger tube in LiBr solution

To discuss local corrosion behavior like pitting and crevice corrosion, cyclic polarization curves of copper(Cu), aluminum brass(Al-brass) and 30% cupronickel(30% Cu-Ni) in 60% LiBr solution at 95℃ is shown in Fig. 3.

According to hysteresis loop of cyclic polarization curves, corrosion current density of 30% cupronickel is less than that of both copper and aluminum brass. Reverse anodic scan of heat exchanger tube materials shows negative hysteresis loop. Especially, anodic current density in reverse scanned area of 30% cupronickel is less than that of forward anodic scan area, and whole anodic scan current density of 30% cupronickel is less than that of both copper and aluminum brass. So, as a result, it is estimated that local corrosion control, such as pitting and crevice corrosion, of 30% cupronickel is very excellent.

In order to inspect quantitative local corrosion characteristics of heat exchanger, repassivation potential, the potential where the loop closes on the reverse scan, and open circuit potential(OCP) of copper, aluminum brass and 30% cupronickel from Fig. 3 is shown in Fig. 4.

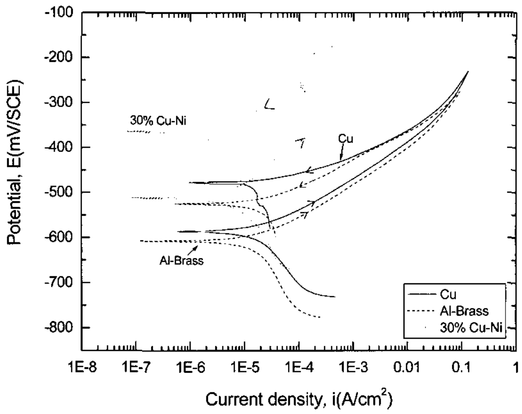


Fig. 3 Cyclic polarization curves of Cu, Al-brass and 30% Cu-Ni for heat exchanger tube in 60% LiBr solution at 95℃

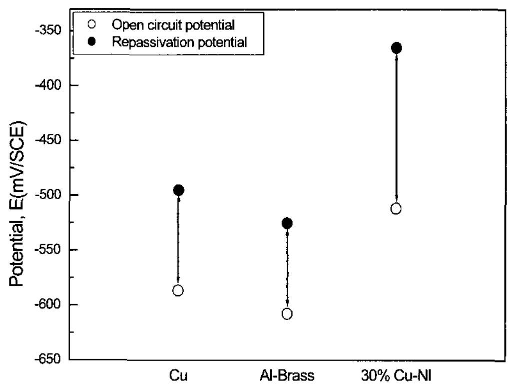


Fig. 4 Repassivation and open circuit potential of Cu, Al-brass and 30% Cu-Ni for heat exchanger tube in 60% LiBr solution at 95℃

In 60% LiBr solution at 95℃, the repassivation potential of heat exchanger tube materials appears higher than open circuit potential. As a result of this, it seems that the effect of local corrosion protection is good. Also, as the difference in potential of 30% cupronickel between repassivation potential and OCP is biggest among tube materials, it is estimated that local corrosion control of 30% cupronickel is remarkably excellent.

3.2 Dissimilar metal corrosion behavior of heat exchanger tube in LiBr solution

To investigate dissimilar metal corrosion behavior of tube materials coupling to tube plate, aluminum bronze, the difference in potential between open circuit potential of tube plate and tube in 60% LiBr at 95℃ is shown in Fig.5.

The difference in OCP between tube and tube plate is high in order of 30% cupronickel 〉 copper 〉 aluminum brass, and the difference of OCP appears on the region from 0~120 mV/SCE. And as difference in OCP of 30% cupronickel in contact with aluminum bronze is over 50 mV/SCE, dissimilar metal corrosion can occur.

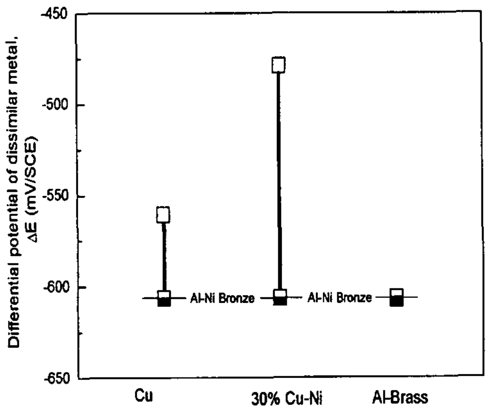


Fig. 5 Differential potential of tube(Cu, 30% Cu-Ni and Al-Brass) coupled with tube plate (Al-Ni Bronze) in 60% LiBr solution at 95℃

Figure 6 shows galvanic current density between cathode(tube materials) and anode(tube plate) in 60% LiBr solution at 95℃ with time passing.

Galvanic current density is high in order of 30% cupronickel 〉 copper 〉 aluminum brass. Especially, as shown Fig. 5, galvanic current density between 30% cupronickel and aluminum bronze is the most high. From the results of Fig. 5 and Fig. 6, it is estimated that dissimilar metal corrosion can occur on the 30% cupronickel in contact with aluminum bronze. But, as shown Fig. 5 and Fig. 6, difference in OCP and galvanic current density between aluminum brass and aluminum bronze is nearly zero. So, dissimilar metal corrosion of aluminum brass in contact with aluminum bronze can be ignored.

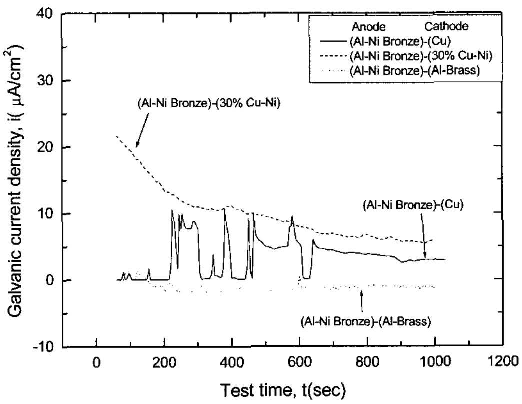


Fig. 6 Differential potential of tube plate (Al-Ni bronze) coupled with tube(Cu, 30% Cu-Ni and Al-brass) for heat exchanger in 60% LiBr solution at 95℃

3.3 Corrosion behavior of heat exchanger by impressed potential

Corrosion behavior of tube materials in 60% LiBr solution at 95℃ with time by impressed potential from OCP to 300 mV/SCE, is shown in Fig. 7.

Current density is high in order of copper 〉 aluminum brass 〉 30% cupronickel. Especially that of 30% cupronickel is greatly controlled than other tube materials. Also, current density of aluminum brass by impressed potential with time is very stable.

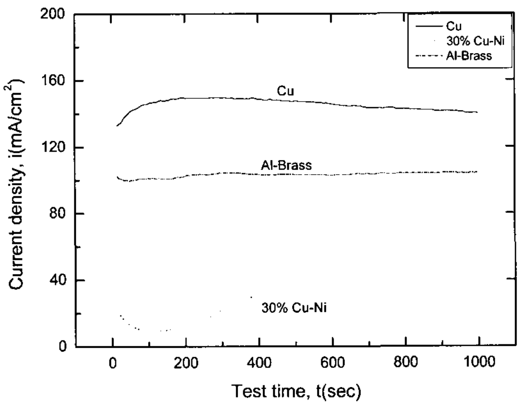


Fig. 7 Corrosion current density of Cu, 30% Cu-Ni and Al Brass vs. test time by impressed potential (300mV/SCE) in 60% LiBr solution at 95℃

4. Conclusion

In this study, local corrosion, galvanic corrosion behavior and corrosion behavior by impressed potential in 60% lithium bromide solution is investigated. The main results obtained are as follows :

(1) The effect of pitting and crevice corrosion control of 30% cupronickel in 60% LiBr solution at 95℃ is extremely excellent.

(2) Dissimilar metal corrosion of 30% cupro nickel coupling to aluminum bronze is the most sensitive.

(3) Current density behavior of tube materials by impressed potential is high in order of copper 〉 aluminum brass 〉 30% cupronickel.

Acknowledgment

This work was partially supported by the Brain Korea 21 Project in 2003.

Reference

[1] S. G. Lee and S. G. Roo, Development of absorption systems, The journal of AREK, Vol.15, No.5, pp. 335~342, 1998

[2] J. R. Ra and G. T. Lee, Absorbent and refrigerant management, The journal of AREK, Vol.15, No.5, pp. 343~352, 1998

[3] U. J. Lim, K. C. Jeong, The Effect of Temperature on Corrosion of Absorption Refrigeration Systems Using LiBr-H2O Working Fluids, KOSME, Vol.26, No.1, pp. 125~131, 2002

[4] D. A. Jones, Principles and prevention of corrosion, 2nd edition, Macmillan Publishing Co., pp. 118~125, 1992

[5] Masayuki Motegi, Keiko Kurokawa, Takashi Susai, Katsuhide Kohtari, Shigeru Komukai, "Corrosion Behavior on a Heat Transfer Surface in Gas Fired Absorption Chillers", Sanyo Techanical Review, Vol.23, No.3, pp. 122~132, 1991

[6] R. S. Levine, "Removing corrosive debris caused by lithium bromide in absorption chillers", PLANT ENGINEERING, Jan., p. 109, 1986

[7] Yoshio Umetsu, Kazuo Tanno and Masahiko Itoh, "Corrosion Inhibition of Carbon Steel, Copper and 70/30 Cupro-Nickel by Sodium Tetraborate and Benzotriazole in Concentrated Lithium Bromide Solution at Elevated Temperature", Boshoku Gijutsu, Vol. 29, No. 5, pp. 233~238, 1980

저 자 소 개

임우조 (林祐助)
1943년 7월생. 당학회 부회장, 한국 부식방식학회 고문, 1975~현재 부경대학교 기계공학부 교수

정기철 (鄭基哲)
1960년 5월생. 당학회 회원, 현재 동명대학 가스냉동과 부교수(공학박사, 기술사)

윤병두 (尹炳斗)
1973년 12월생. 1997년 부경대학교 기계공학과 졸업, 1999년 부경대학교 대학원 졸업(석사), 현재 부경대학교 박사과정 수료.