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Study on the Cavitation Damage of Cupronickel(70/30) Tube for Gas Absorption Refrigeration Machine

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Abstract : The use of gas absorption refrigeration machine has considerably increased because of the shortage of the electric power in the summer and the regulation of freon refrigerant. Gas absorption refrigeration machine consists of a condenser, a heat exchanger, supplying pipes, a radiator etc. This system is likely to be corroded by acid, dissolved oxygen and gases. Cavitation erosion-corrosion by flow velocity of cooling water may happen in absorption refrigeration machine. In these cases, erosion and corrosion occur simultaneously. Then, it makes a serious damage with synergy effect.

Therefore, this paper was studied on the cavitation damage of cupronickel(70/30) tube for gas absorption refrigeration machine. In the 30℃ tap water, linear polarization test and anodic polarization test were carried out for copper(C1220T-OL) and cupronickel(70/30) tube. Also, cavitation erosion-corrosion behavior of cupronickel (70/30) tube was considered. The main results are as following: (1) In the linear test, the corrosion current density of cupronickel(70/30) is higher than that of copper. (2) The erosion-corrosion rate of cupronickel(70/30) displayed later tendency than that of copper by vibratory cavitation in cooling water. (3) In cooling water, the progress mechanism of erosion-corrosion rate of copper and cupronickel(70/30) follows a pattern of incubation, acceleration, attenuation and a steady state period.

Key words : Absorption refrigeration systems, Cupronickel(70/30) tube, Anodic polarization, Cavitation damage, Progress mechanism of erosion-corrosion

1. Introduction

Vapor compressed refrigeration system is restricted by the environmental regulation. Because freon refrigerant causes environmental pollution problem such as ozone layer destruction and greenhouse effect. However, the gas absorption refrigeration machine recently applies water as refrigerant instead of freon in order to decrease exhaustion of the atmospheric pollution substances.

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This system uses gas as a power source to minimize electric energy consumption. The use of this system is increased considerably[1]-[3].

The heat exchanger part of this system consisted of condenser, absorber and evaporator, and its cooling water is fresh water. Due to increase fossil energy consumption, river water for cooling water becomes acidification or contamination. Therefore, this heat exchanger will be corroded by acid and dissolved oxygen[4].

Cavitation erosion-corrosion by flow velocity may happen in this system. This erosion -corrosion damage occurs often in heat exchanger, piping, pump, ship propeller, valve etc.. In this case, there will be mechanical erosion and electrochemical corrosion at the same time. Then, the synergy effect makes less efficiency and shorten the life span of mechanical device. Hence, this study on cavitation erosion-corrosion damage of heat exchanger was requested[5]-[7].

In this study, anodic polarization test was carried out in fresh water to observe the electrochemical polarization behavior of tubing material(copper and cupronickel (70/30)). And progress mechanism of cavitation erosion-corrosion was considered during the test.

2. Test material and experimental method

2.1 Test material and specimen

Test materials used in this study are copper(Cu) and cupronickel(70/30), which are heat exchanger tube material. And Table 1 and 2 show the chemical compositions and mechanical properties of used material. The effective exposure area of specimen used in the polarization test is 1.0 cm^2 and the other area was electrically isolated by mounting. The cavitation erosion-corrosion specimen shown in figure 1 was manufactured according to a circular sample with a diameter of 18 mm and a thickness 2 mm. To fix specimen in the cavitation occurrence, test sample was fixed to a jig.

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)	Elongation (%)
	372	42

Table 3 Chemical compositions and mechanical properties of cupronickel(70/30)

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	

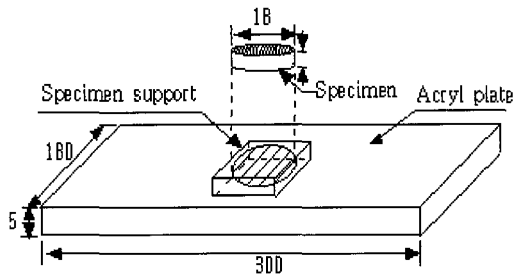


Fig. 1 Shape and dimension of specimen for cavitation erosion test(unit:mm)

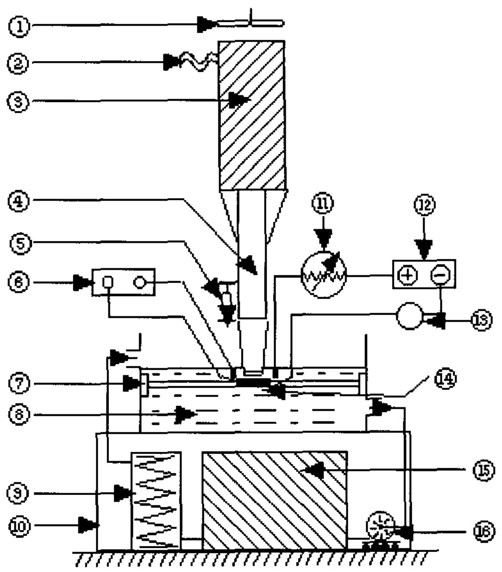
2.2 Experimental apparatus and method

To make observations of anodic polarization characteristics, the electrochemical polarization test method was used. This method will be carried out non-destructively and make the test time of this method shorter than other corrosion tests.

The experimental system applied to local corrosion test consists of M 352 potentiostat /galvanostat(EG&G co.), personal computer equipped with M352 software for data acquisition and printer in order to record polarization curves. For this test, reference electrode was SCE(Saturated Calomel Electrode) and the counter electrode was high density carbon.

The experimental apparatus, shown in figure 2 used to cavitation erosion-corrosion test, is vibratory acceleration tests applying supersonic waves. Here, the resonance frequency of vibrator was done by 20kHz according to ASTM standard, and amplitude done regularly by 20μm.

To protect galvanic corrosion, corrosion cell was manufactured by acryl. The sample and horn's interval was measured to feeler gauge and vernier calipers. Also, weight lose of sample by cavitation erosion-corrosion damage was measured by 1/10,000g's electron balance. Then, the surface damage state was filmed at interval of 30 minutes by a digital camera. The corrosive environment used fresh water as cooling water, and experimental temperature was room temperature.



1. Cooling fan	2. Power supply
3. Transducer	4. Horn skirt
5. Dial gauge	6. Potentiometer
7. Specimen supporter	8. Soluble liquid
9. Temp. regulator	10. Stand bed
11. Rheostats	12. DC power supply
13. Ampere meter	14. Specimen
15. Power control box	16. Circulating pump

Fig. 2 Schematic diagram of cavitation erosion-corrosion test apparatus

3. Results and discussion

3.1 Uniform corrosion behavior

Fig. 3 shows linear polarization curves of copper and cupronickel(70/30) in fresh water(ρ=5,000 $\Omega \cdot$ cm, T=30℃).

Electrode potential of copper became nobler than that of cupronickel(70/30). The current density changes of cupronickel appear lower than those of copper. Therefore, the polarization resistance of cupronickel appears higher than that of copper.

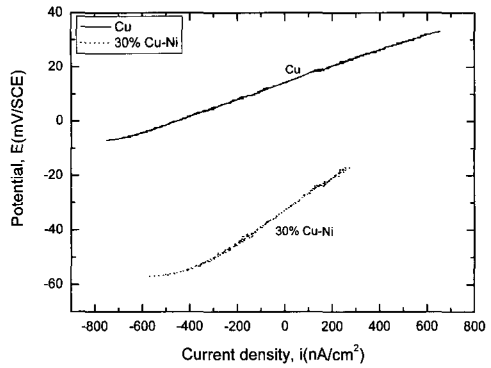


Fig. 3 Linear polarization curves of Cu and cupronickel(70/30) for heat exchanger tube in fresh water(T=30℃)

3.2 Local corrosion behavior of tube

If stress or flow velocity is acted to metal construction, the anodic potential of metal will be risen and local corrosion is activated. Fig. 4 shows anodic polarization curves of copper and cupronickel(70/30) in fresh water.

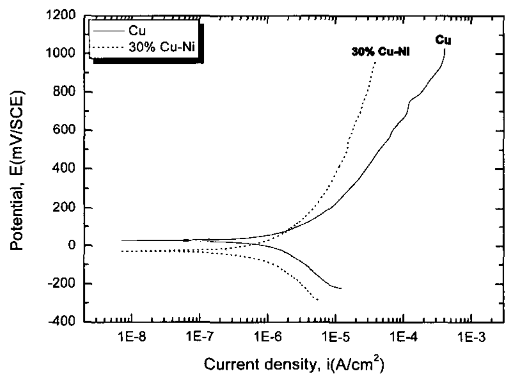


Fig. 4 Anodic polarization curves of Cu and cupronickel(70/30) for heat exchanger tube in fresh water

Despite anodic potential rises, the corrosion current density of cupronickel (70/30) was controlled more than copper. As the anodic potential rises, the corrosion current density of copper flows much more than that of cupronickel (70/30). It was considered that Ni composition of cupronickel(70/30) acts as being passive.

3.3 Progress mechanism of cavitation erosion-corrosion rate

Thiruvengadam presents progress mechanisms of erosion-corrosion rate for each kind of material with cavitation occurrence in fluid. Fig.5 shows the erosion-corrosion rate-time curve(R-t curve)[8]-[10]. Here, Ⅰ: Incubation period (I.P), Ⅱ : Acceleration period (AC.P), Ⅲ : Attenuation period(AT.P), Ⅳ : Steady state period(S.PI) were divided by 4 steps, and Plesset, Devine etc. are present opinions for the progress mechanism of erosion-corrosion rate.

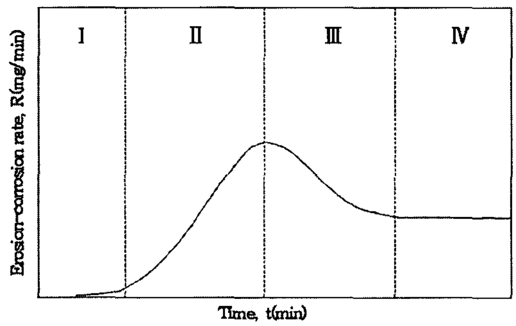


Fig. 5 Progress mechanism of erosion-corrosion rate by cavitation

Fig. 6 shows erosion-corrosion rate by vibratory cavitation of copper and cupronickel (70/30) with time in fresh water.

The erosion-corrosion rate of cupronickel (70/30) displayed a later tendency than copper by vibratory cavitation in fresh water. In these incubation period, plastic deformation showed on sample surface by shock power of bubbles generated by cavitation occurrence, and oxide film and double layers separated slowly. Finally the pit nucleus by erosion-corrosion was formed.

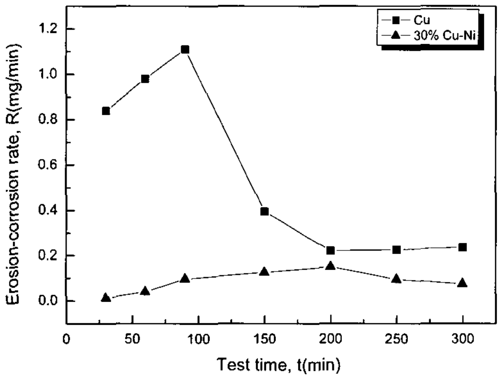
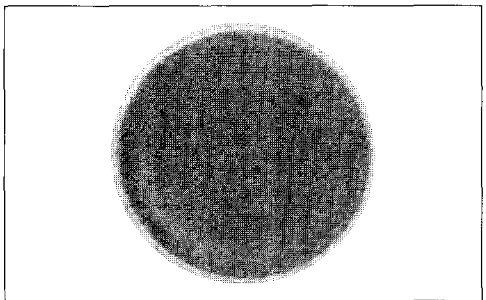
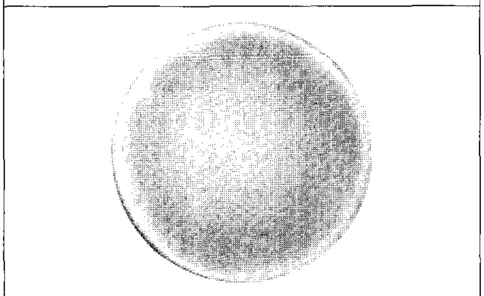


Fig. 6 Erosion-corrosion rate of Cu and cupronickel (70/30) by cavitation vs. test time in tap water



(a) I. P.(5 min.) of Cu



(b) I. P.(60 min.) of cupronickel(70/30)

Photo. 1 Appearance of incubation period for Cu and cupronickel(70/30) by cavitation erosion-corrosion in fresh water

Photography 1 shows each sample's surface aspect considered by incubation period of copper and cupronickel(70/30). In this period, surface roughness of materials by cavitation erosion- corrosion became larger, but weight loss was not influenced greatly. Cosequently, it was presumed that this is early characteristic resistance of materials.

The acceleration period of cupronickel (70/30) was delayed than that of copper with incubation period. The number and depth of pit was increased in acceleration period, also, erosion-corrosion rate by vibratory cavitation became faster as pit grew.

Attenuation period of copper became faster than that of cupronickel(70/30). In attenuation period, although pit numbers does not increased, some pit depth and area grew. By vibratory cavitation, erosion-corrosion rate dropped rapidly. In this attenuation period, the impact force of cavitation pit was mitigated gradually by shock absorbing action on interior of pit formed on surface of the sample. Therefore, weight loss rate of cavitation erosion-corrosion was decreased.

The steady state period of copper was faster than that of cupronickel(70/30). As impact force of the cavitation pit is similar to recovery rate of passive film on surface, the weight loss becomes almost constant.

4. Conclusion

In this study, the polarization behavior and progress mechanism of cavitation erosion-corrosion of copper and cupronickel

(70/30) tube were investigated in fresh water. The main results are obtained as follows:

(1) The corrosion current density of cupronickel(70/30) is higher than that of Cu.

(2) The erosion-corrosion rate of cupronickel (70/30) displayed later tendency than that of copper by vibratory cavitation in cooling water.

(3) The progress mechanism of erosion-corrosion rate of copper and cupronickel (70/30) follows a pattern of *incubation, acceleration, attenuation* and a steady state period.

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