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ULTRASONIC VIBRATIONS FOR IMPROVING ABSORPTION CHILLERS PERFORMANCES

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Abstract: - Paper present an original method for improving evaporation and absorption processes in absorption chiller systems. The method is based on ultrasonic vibrations. Vibrations allow to reduce the surface tension of working fluid and to increase interface area between absorber fluid and refrigerant. Measurements have been carried out by means of an experimental device equipped with ultrasound generator. Results show that vibrations produce improvements on absorption and evaporation phenomena.

Key-Words: - Absorption chiller, evaporation, ultrasonic vibrations.

1 Introduction

The growing electrical energy demand for summery conditioning has encouraged researchers to study new solution for low power chillers: among available technologies, absorption chillers may return to play an important role. Furthermore, thanks to the progressive reduction of both installation and maintenance cost and energy consumption, their employment may become more and more diffuse. An experimental device has been built at University of Perugia Applied Physic laboratory to test the influence of the ultrasonic vibrations on the evaporation-absorption phenomena. The device is made of two heat exchangers, equipped with piezoelectric transducers that may work alternatively as generator-condenser pair or as absorber-evaporator pair. This paper describes the experimental apparatus, the measurements and preliminary results.

2 Aims of research

Process efficiency can be improved by two ways: choosing a high vaporization heat cooling fluid with an or increasing the evaporated flow rate [1]. The aim of this research is to improve of the evaporative process and mass exchange between the evaporator and the absorber by ultrasonic vibrations. Ultrasonic vibrations act on liquid surface tension, dimming molecular bonds strenght and increasing free liquid surface because of induced mechanical vibrations.
Several studies [2][3][4] have demonstrated that vapour absorption depends on liquid surface tension. Moreover, the vapour absorption process produces a low concentration of absorbent onto mixture surface layer. Such phenomenon, known as "Marangoni effect, reduces the mixture absorption performances. Molecular turbulence on liquid layer improved by mechanical vibrations is expected to reduce surface tension [5] (improving kinetic and molecular diffusivity) and to increase the absorbent surface.

3 Experimental Apparatus

The experimental apparatus is constituted by two steel heat exchangers (Exchanger I and Exchanger II) which are shown in Figure 1. Each heat exchanger has been equipped with the following devices:

- copper coil for fluid cooling (Fig. 1, reference (1));
- electrical resistor for heating 1200 W (Fig. 1, reference (2));
- two temperature probes (temperature range 0 - 100°C) located respectively at the bottom and at the top of the exchanger (Fig. 1, reference (3));
- digital pressure probe (-1/ +1 bar) (Fig. 1, reference (4));
- level meter (Fig. 1, reference (5));
- ultrasonic probe (Fig. 1, reference (8)).

Furthermore, heat exchangers have been equipped with manifolds (Fig. 1, reference (6)) for fluids filling and for vacuum pump connection.
Vacuum is maintained inside heat exchanger thank to watertight taps and o-ring seals on

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each flange. Piezoelectric transducers (one for each exchanger) have been positioned on the container lateral surface.
The connection between heat exchangers has been made by a pipe with a valve (Fig.1 reference (7)).

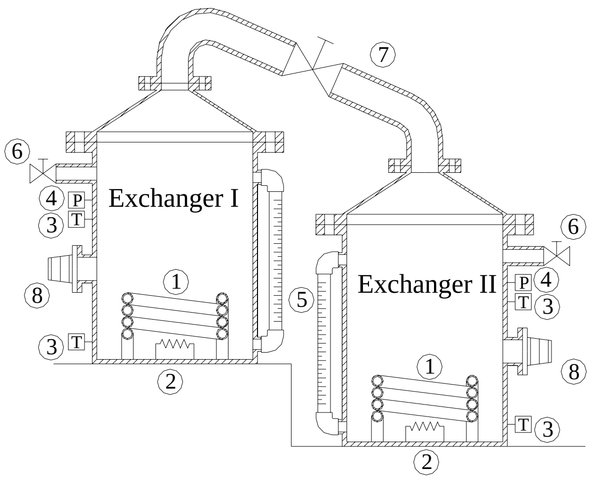

Fig.1 Experimental apparatus layout.

4 Ultrasonic generator

The ultrasonic generator (Fig. 2) is made of a resonant circuit that generates sinusoidal waves (f = 22500 Hz) which are converted into mechanical oscillations by two piezoelectric transducers.
Each piezoelectric transducer electrical power absorption is 50W, which is converted into 20 W mechanical power.

Fig.2. Ultrasonic generator and piezoelectric transducer.

Piezoelectric transducers are constituted by circular electrostrictive elements made of zirconate - titanate lead. Each transducer is equipped with a flange which matches the heat exchanger flange as shown in Figure 3.

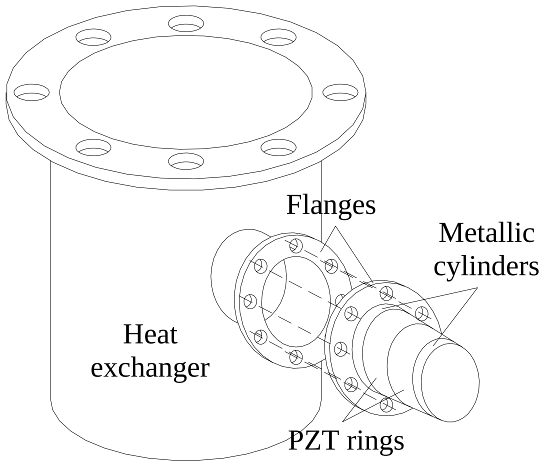

Fig.3. Transducer-heat exchanger coupling scheme.

5 Experimental analysis

Inside heat exchangers, typical conditions of a LiBr-H_2O absorption chillers have been set. Fluid pressure and fluid temperature have been set as follow:

Evaporator pressure	4 kPa.
Evaporator temperature	7 °C.
Absorber pressure	4 kPa
Absorber temperature	35 °C

Temperature and pressure are kept to the previous values by automated regulator system.

6 Measurements

A measurement campaign was carried out in the ‘absorber-evaporator pair’ configuration: Exchanger I as evaporator and Exchanger II as absorber.
The water mass rate which evaporates from Exchanger I and is absorbed into Exchanger II was determined for four different condition:

a. Ultrasonic System is set *off* inside both exchangers (E_{off}, A_{off});
b. Ultrasonic System is set *on* inside Exchanger I and is set *off* inside Exchanger II (E_{on}, A_{off});
c. Ultrasonic System is set *on* inside Exchanger II and is set *off* inside Exchanger I (E_{off}, A_{on});
d. Ultrasonic System is set *on* inside both exchangers (E_{on}, A_{on}).

The following procedure has been carried out to determine evaporated and absorbed mass in each exchanger:

1. heat exchangers, I and II, are filled respectively with distilled water and Lithium Bromide mixture (50/50 Wt %); their levels are measured by means of the level meter (5);
2. fluid temperature is set by the thermoregulator system;
3. pressure inside of two exchangers is set;
4. bypass valve (7) is opened;
5. level in Exchanger I is monitored to determine the evaporated mass versus time.

Condition *a* was employed to calculate the water evaporation rate without mechanical vibrations. Condition *b* was employed to estimate the mechanical vibrations influence on evaporation phase. Condition *c* was employed to estimate the mechanical vibrations influence on absorption phase. Condition *d* was employed to estimate the mechanical vibrations influence on evaporation and absorption phases simultaneously.

7 Experimental results

Evaporated water inside Exchanger I and absorbed vapour inside Exchanger II are shown on Table 1 and 2 for a 60 minutes test duration. Results are given for each condition (*a*, *b*, *c* and *d*)).
Table 1 shows that vibrations influence on both evaporation and absorption processes. The maximum effect on evaporation rate occurs on *d* condition. Such condition is characterized by higher electrical power absorption too. By Table 2, condition *c* shows the highest evaporation rate/power absorption ratio.

Table 1 Evaporation rate for different conditions.

Time range [minutes]	**Evaporation rate [g/min]**			
	Condition *a*	Condition *b*	Condition *c*	Condition *d*
0 ÷ 20	0.0010	0.0085	0.0382	0.0585
20 ÷ 40	0.0003	0.0027	0.0106	0.0198
40 ÷ 60	0.0001	0.0007	0.0035	0.0063

Table 2. Evaporated mass after 60 minutes.

	Condition *a*	Condition *b*	Condition *c*	Condition *d*
Evaporated mass [g]	0.028	0.237	1.047	1.692
Energy spent for vibrations [kJ]	0.00	180	180	360

Thus, on condition *c*, energy balance was carried out to evaluate the energy saving due to mechanical vibrations employment. The energy saving is given by the difference between thermal energy saved for water mass evaporation and electrical energy spent by the transducer during test:

$$E = E_S - E_A \quad (1)$$

E_S is found by the following relation:

$$E_S = r \cdot (m_c - m_a) \quad (2)$$

E_A is given by:

$$E_A = P_E \cdot t \quad (3)$$

By calculating (2) and (3), eq. (1) results:

$$E = - 177.5 \text{ kJ} \quad (4)$$

Eq. (4) says that no effective energy saving occurs. This fact is probably due to the vibrational mismatching between transducers and mixture. Enhancing vibrational matching it is expected to make vibrations employment viable for improving absorber chillers performances.

Conclusion

In this paper influence of ultrasonic vibrations on absorber chillers performances is tested. For that an “ad hoc” experimental apparatus has been set up. An improvement of absorption and evaporative phenomena has been attained under ultrasonic excitation; however no energy saving couldn’t be achieved because of the amount of energy spent for the ultrasonic excitation. An improvement of matching between ultrasonic transducers and mixture is now under study which is expected to make energy saving viable.

List of Symbols

E	=	Energy saving [kJ].
E_A	=	Thermal energy saved for water mass evaporation [kJ].
E_S	=	Electrical energy spent by the transducer [kJ].
m_a	=	Evaporated mass in condition *a* [kg].
m_c	=	Evaporated mass in condition *c* [kg].
P_E	=	Transducer electrical power [W].
r	=	Heat of vaporization of water at 7°C [kJ/kg].
t	=	Test duration [s].

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On	=	With ultrasonic system;
sOff	=	Without ultrasonic system.

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