COOLING PERFORMANCE IMPROVEMENT OF AN AIR-CONDITIONER BY ULTRASONIC WAVE

Tanongkiat Kiatsiriroat[1], Nattaporn Chaiyat[2] and Ratchatanee Sanjit[1]

[1] Department of Mechanical Engineering, Chiang Mai University, Chiang Mai, Thailand
[2] Energy Research Center and Division of Renewable Energy, Faculty of Agricultural Production, Maejo University, Chiang Mai, Thailand

Abstract

This paper presents a concept to improve cooling performance of an air-conditioner by ultrasonic wave. For the modified system, a set of ultrasonic wave having frequency of 42 kHz was installed at the evaporator and the condenser to increase turbulence of refrigerant in the heat exchange components. For the evaporator, less amount of condensed water at the evaporator fin was found and the heat transfer rate could be increased. Moreover, a cooling performance indicator of the air-conditioner in a term of energy efficiency ratio (EER) was presented as a function of the air entering temperatures at the evaporator and the condenser. From the results, it could be seen that the cooling capacity of the evaporator after improvement could be increased around 10% and 15% when 1 unit and 2 units of ultrasonic generators were installed, respectively. For the condenser, the ultrasonic wave did not show the significant improvement of the unit. When the power consumption of the ultrasonic generator was included, for the evaporator with ultrasonic generator, it could be found that the air conditioner with 1 unit of ultrasonic generator gave similar result with that of the ordinary one without the ultrasonic generator. With 2 units of ultrasonic generator, the EER of the modified system could be improved around 8% compared with that of the normal system.

Keywords: Ultrasonic wave, Air-conditioner, Cooling, Heat transfer improvement.

1. Introduction

For an air-conditioner, various techniques to improve its cooling performance have been developed such as a frequency control for adjusting suitable compressor speed to match with the cooling load at its evaporator. Recently, use of ultrasonic wave has been done to enhance heat transfer rate in thermal equipments. Oh et al. [1] presented the results of ultrasonic wave in a melting heat transfer. It could be found that the melting was faster than that of the normal process at around 2.5 times. Sriwichai et al. [2], Tachana et al. [3] and Wongtom et al. [4] studied the heat transfer rate enhancement of boiling in a thermosyphon heat pipe having an ultrasonic generator installed at the evaporator section. It could be found that the ultrasonic wave could increase the heat transfer rate.

The main objective of this work was to study cooling performances of an air-conditioner having ultrasonic generators installed at the evaporator and condenser. The indicator on the energy consumption was presented in a term of energy efficiency ratio (EER) and the results had been compared with that of the normal unit.

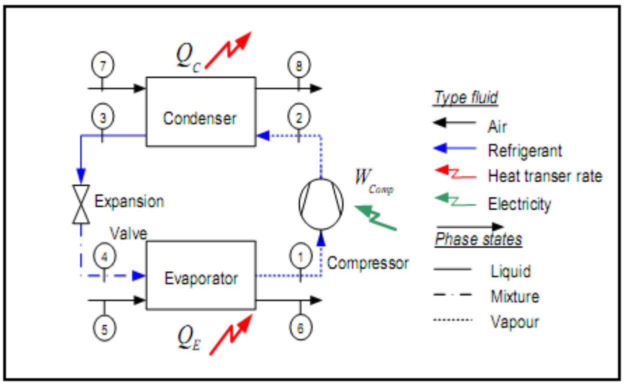

Figure 1 Schematic diagram of the normal air-conditioner system.

2. Mathematical model

Figure 1 shows a schematic diagram of a normal vapor compression air-conditioner system (VCHP).

The basic equations for the behavior of each component in the VCHP cycle are as follows:

- Evaporator

$$Q_E = \dot{m}_{dry\,air} C_{P,dry\,air}(T_5 - T_6) + M_{water} h_{fg} \quad (1)$$

- Condenser

$$Q_C = \dot{m}_{dry\,air} C_{P,dry\,air}(T_8 - T_7) \quad (2)$$

- Energy efficiency ratio (EER)

$$EER = \frac{Q_E}{W_{Comp}}, \quad (kW_{th}/kW_e) \quad (3)$$

The energy efficiency ratio (EER_{VCHP} - a ratio of heat at the VCHP evaporator and the electrical power consumption) could be set up as a function of temperature difference between the air temperature entering the condenser ($T_{C,i}$) and the air temperature entering the evaporator ($T_{E,i}$), the empirical correlations could be found in forms of

$$EER_{VCHP} = a(T_{C,i} - T_{E,i}) + b. \quad (4)$$

When a and b are constants which could be obtained the testing results.

3. Materials and Methods

An experimental test was carried out with a 1 TR vapor compression air conditioner. There were1 unit or 2 units of 42 kHz ultrasonic generators installed at the evaporator and condenser as shown in Figure 2. The positions of ultrasonic generators were shown in Figure 3.

The specifications of the main components of the air conditioner are given in Table 1.

Figure 2 Installation of ultrasonic generators at the evaporator of the tested air conditioner.

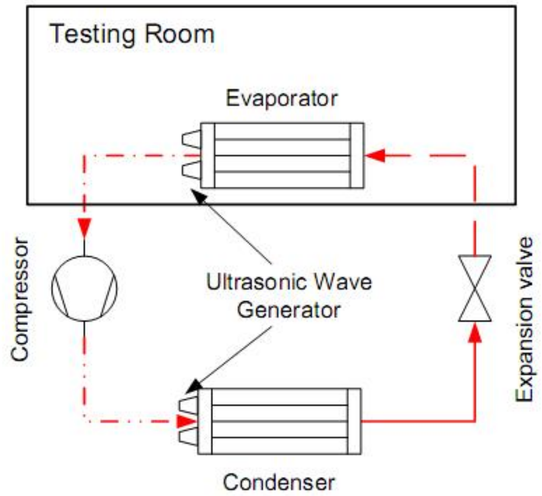

Figure 3 Positions of the ultrasonic generators for the tested air-conditioner.

Table 1. The specifications of the main components of the tested air-conditioner and the ultrasonic set.

Devices	Properties
Evaporator	
Type	Fin and Tube heat exchanger
Material	Copper and aluminum
Capacity	3.516 kW
Dimension	Tube Size (OD) 5.0 mm
Fins per inch	18 FPI
No of row	2 Rows
No of column	15 Columns
Compressor	
Type	Hermetic compressor (Rotary)
Material	Cast Iron
Refrigerant	R-134a
Capacity	1.434 kW
Compression ratio	6.0 Max
Condenser	
Type	Fin and Tube heat exchanger
Material	Stainless steel
Capacity	5.275 kW
Dimension	Tube Size (OD) 7.0 mm
Fins per inch	18 FPI
No of row	2 Rows
No of column	36 Columns
Expansion valve	
Type	Orifice Type Thermo static
Material	Bronzed
Capacity	3.516 kW
Pressure ratio	3.0
Ultrasonic	
Frequency	Frequency 42 kHz
Power	150 W
Testing room	

Devices	Properties
Size (w x l x hh, m)	3 m x 3 m x 3 m

4. Results

Figure 4 shows the cooling capacity of the air-conditioner with and without ultrasonic generator at the evaporator. Since the ultrasonic wave increases turbulence in the refrigerant flow and moreover, less accumulation of condensed water at the evaporator coil could be achieved then the heat transfer at the component is higher than the normal unit. Therefore, the ultrasonic wave could improve the cooling capacity of the air-conditioner. From the experiments, 1 unit and 2 units of ultrasonic generators could increase the cooling capacity at around 10% and 15% compared with the normal air-conditioner, respectively.

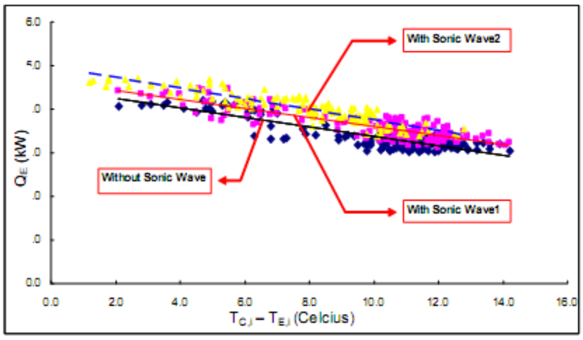

Figure 4 Comparison of the cooling capacity of the evaporator with and without the ultrasonic set.

Figure 5 shows the EER_{VCHP} of the air-conditioner with and without the ultrasonic set at the evaporator. It could be seen that the EER_{VCHP} of the modified system with 1 unit of ultrasonic generator and the normal system gave similar result because of the electrical power consumption of the ultrasonic generator which was around 150 W/set. While the EER_{VCHP} of 2 units of ultrasonic generators could be improved at around 8% compare with the normal air-conditioner.

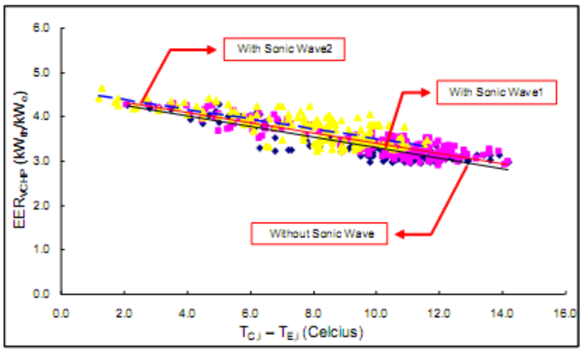

Figure 5 Comparison of the EER for the evaporator with and without the ultrasonic set.

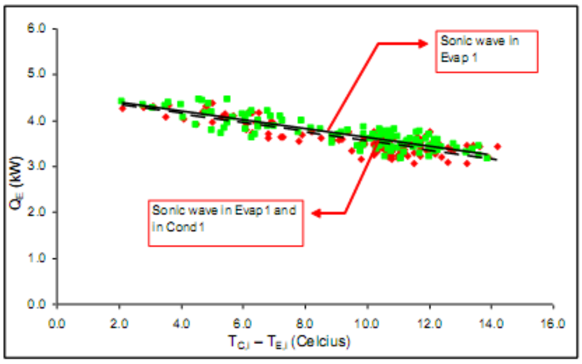

Figure 6 Cooling capacity of the air-conditioner with the ultrasonic sets at the evaporator and condenser.

For the ultrasonic generators installation both at the evaporator and the condenser, it could be found that the cooling performance was similar to the unit having ultrasonic generator at the evaporator only. The results were shown in Figure 6. Therefore, it could be recommended to use ultrasonic wave at the evaporator only.

5. Conclusion

1. With the ultrasonic generator installation at the evaporator of the tested air-conditioner, the ultrasonic wave could increase the

cooling capacity around 10% and 15% with 1 unit and 2 units of ultrasonic generators have been installed, respectively.

2. For the EER of the air-conditioner, 1 unit of ultrasonic generator gave similar result with the normal air-conditioner while 2 units of ultrasonic generators could improve the performance around 8%.
3. When the ultrasonic generators were installed both at the evaporator and the condenser, the cooling performance was similar to that at the evaporator only. Therefore, it is no need to install the ultrasonic generator at the condenser.

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7. References

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8. Nomenclature

Nomenclature	
Cp	Heat capacity, (kJ/kg.K)
m	Mass flow rate, (kg/s)
Q	Heat rate, (kW)
T	Temperature, (°C)
W	Work, (kW)
Subscript	
C	Condenser
Comp	Compressor
E	Evaporator
i	Inlet
th	Thermal
e	Electrical