KSCOP Characteristics of Fixed and Inverter Type Heat Storage Heat Pump and Simulation Study

Chan Ho Song, senior researcher, Korea Institute of Machinery & Materials, 156 Gajeongbuk-Ro, Yuseong-Gu, Daejeon, 305-343, Korea
Ook-joong Kim, chief researcher, Korea Institute of Machinery & Materials, 156 Gajeongbuk-Ro, Yuseong-Gu, Daejeon, 305-343, Korea
Ho Young Jang, researcher, Korea Institute of Machinery & Materials, 156 Gajeongbuk-Ro, Yuseong-Gu, Daejeon, 305-343, Korea
Seok Ho Yoon, chief researcher, Korea Institute of Machinery & Materials, 156 Gajeongbuk-Ro, Yuseong-Gu, Daejeon, 305-343, Korea

Abstract: The present study has been conducted for a heat pump system for hot water supply using air as a heat source. Heat pump with inverter compressor was compared with fixed compressor type system and KSCOP(Korean Seasonal COP) conditions were applied to the system. Sensitivity analysis in test conditions was carried out. It is found that inverter type system can deal with the various load when compared with fixed type system, and system design at the outdoor condition 2/1℃ is important. Actual indoor load was realized Using Trnsys software. 2 type systems were modeled and heating operation was conducted under the given heat load. As a result, it was found that inverter system could deal with various load very effectively.

Key Words: heat pump, heat storage, KSCOP, simulation

1 INTRODUCTION

In general, heat pump can produce 3~4 times more heat compared to the electric heater with the same power and get the limelight as an excellent energy-saving appliances. When the water heater with electric heater is replaced by the heat pump, the power cost is reduced by 1/3. In addition, by using the exhausted heat as a heat source of heat pump in the building, the system performance can be increased and daytime cooling loads which are main factors in the summer electric peak can be moved to night time (Choi, et.al., 1998, Park, et.al., 2012, Ko, et.al., 2012).

In Korea, since 1993, the Korea Electric Power Corporation(KEPCO) is supplying the night electric unit that performs cooling in the daytime and produces ice or cold water in the night time (currently 11:00 p.m. to 9:00 a.m.) when the amount of the electric power in the night time is smaller than that in the daytime. Nowadays the heat pump with heating and cooling is being expanded with various heat sources such as air, geothermal, etc.(KEPCO, 2006).

However, the performance of the air source heat storage type heat pump using night time electric power is not verified under the various load and ambient conditions. COP(coefficient of performance) in heat pump performance is important for standard condition, but recently SCOP(Seasonal COP) which is calculated considering annual load, is getting more important.

In this study, hot water supplying heat pump system with heat storage is introduced and two type systems which are fixed compressor type and inverter compressor type, are compared under KSCOP(Korean Seasonal COP). Simulation using Trnsys software is also conducted

for indoor room. From these results, the characteristics of the heat pump system will be suggested.

2 EXPERIMENTAL SETUP

2.1 KSCOP

KSCOP test conditions that KEPCO(Korea's Electric Power Corporation) suggest are shown in Table 1. In these test conditions, heating capacity and power consumption are measured and COPs in cold, medium, warm region are calculated. Each regional SCOP calculation can be obtained considering weighting value in corresponding to test temperature. The test temperatures are four different areas, that is, -15℃, -7℃, 2/1℃ (dry/wet bulb temp.), 7/6℃ and each regional weighting value is shown in Table 1. Therefore regional SCOP can be expressed as follows.

$$\mathrm{SCOP}_C = 0.07\mathrm{COP}_{@-15} + 0.39\mathrm{COP}_{@-7} + 0.39\mathrm{COP}_{@2} + 0.15\mathrm{COP}_{@7} \quad (1)$$

$$\mathrm{SCOP}_M = 0.02\mathrm{COP}_{@-15} + 0.22\mathrm{COP}_{@-7} + 0.48\mathrm{COP}_{@2} + 0.28\mathrm{COP}_{@7} \quad (2)$$

$$\mathrm{SCOP}_W = 0.05\mathrm{COP}_{@-7} + 0.48\mathrm{COP}_{@2} + 0.47\mathrm{COP}_{@7} \quad (3)$$

Four different test conditions occur as water inlet temperature in system is different. The water inlet temperatures are 40, 50, 60, 70℃ and outlet temperature is 10℃ higher than inlet temperature. The test conditions along with inlet temperature are shown in Table 2. The heating capacities in -15℃, -7℃, 2℃, 7℃ are 18/10.8/7.2 kW, 14/8.4/5.6 kW, 10/6/4 kW and 8/4.8/3.2 kW respectively. The COP is defined as the ratio of heating capacity divided by power consumption. The COP to the ambient temperature is calculated as the mean value of the COP which is obtained under the water inlet temperature.

Table 1: Weighting Factors in KSCOP

Temperature	COP	Cold region	Medium region	Warm region
-15℃/-	COP@-15	7%	2%	0%
-7℃/-	COP@-7	39%	22%	5%
2℃/1℃	COP@2	39%	48%	48%
7℃/6℃	COP@7	15%	28%	47%
KSCOP		SCOP_C	SCOP_M	SCOP_W

Table 2: KSCOP test conditions

In/out water temperature (℃)	Ambient temperature	-15℃	-7℃	2℃/1℃	7℃/6℃
	Capacity (kW)	18/10.8/7.2	14/8.4/5.6	10/6/4	8/4.8/3.2
40/50	COP	C1	C5	C8	C10
50/60	COP	C2	C6	C9	

60/70	COP	C3	C7		
70/80	COP	C4			

2.2 Experimental procedure

In this study, the Ph diagram of the system is displayed in Fig.1. It consists of cascade cycle where bottom cycle uses R410A and top cycle uses R134a. Air side heat exchanger is fin-tube heat exchanger and plate heat exchanger is used in refrigerant-water heat exchanging. The experiment was conducted in 20 hp-calorimeter which includes water supply unit and adjusts supplying water temperature and mass flow rate (Fig. 2). Two different systems with same capacity are experimented where those systems are fixed and inverter compressor type.

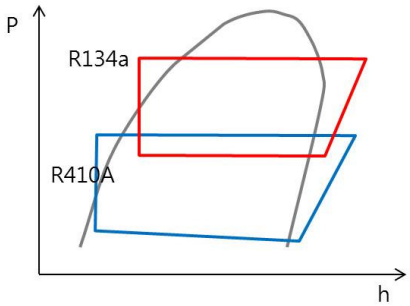


Fig. 1 Ph diagram of cascade cycle

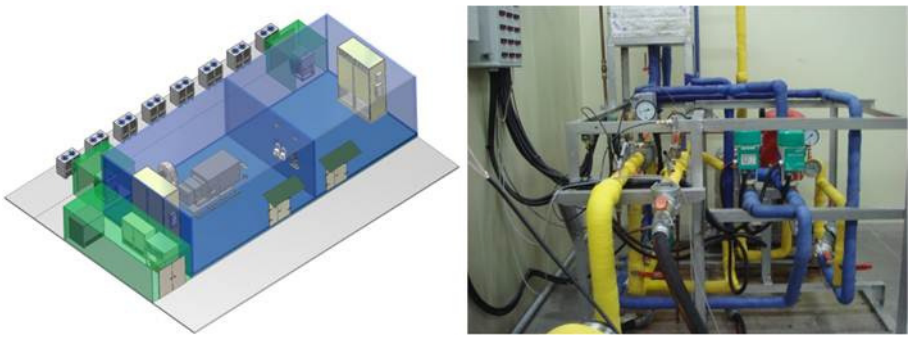


Fig. 2 Calorimeter with water supply system

2.3 Test results

Figure 3 shows the results that are heating load and capacity along with outdoor temperature at inlet water temperature 40℃. The two different systems - fixed type and inverter type are compared. In case of fixed type system, it is designed to meet the load at -15℃. In this reason, the performance of the system is better than that of inverter system under low temperature condition. However as the outdoor temperature increases and the heating load decreases, it is found that the capacity in fixed type system becomes bigger and the power consumption remains the same level. In comparison, inverter system is found to be very effective in various loads. COP at -15 ℃ ambient temperature and 40 ℃ water inlet temperature is 2.27 in fixed type and 1.90 in inverter type, respectively. On the other hands,

at 70℃ water inlet temperature, COPs are 1.76 in fixed type and 1.67 in inverter type. In case that system operates in higher ambient temperature, inverter system can prevent its capacity being excessive and consequently it has an advantage of avoiding unnecessary energy waste.

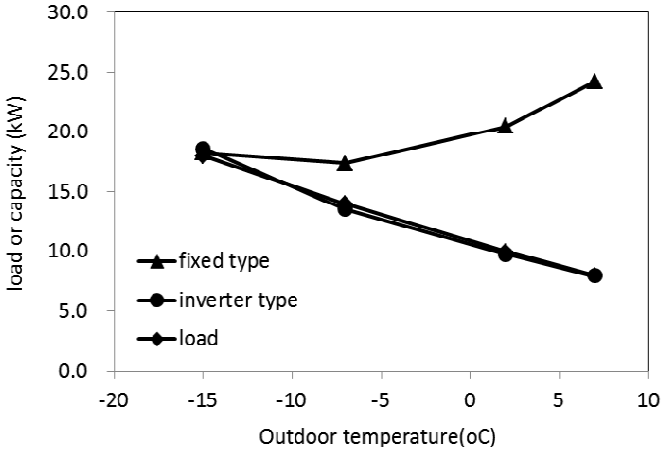


Fig. 3 Calorimeter with water supply system

Figure 4 shows the COP variation of inlet water temperature at -15℃ outdoor temperature. The fixed type system has higher COP than the inverter type system and as inlet water temperature increases, the condensing pressure in R134a cycle increases, which leads to increase compression work. From this mechanism, it is shown that overall COP becomes small. The figure means that the fixed type system which is optimised for -15℃ outdoor temperature is better in COP compared with inverter system. Figure 5 shows the COP variation of the outdoor temperature at 40℃ of inlet water temperature. The fixed type system has higher COP that inverter system in the -15℃ ambient temperature condition, but in higher ambient temperature, inverter system is getting better as shown in Fig. 5. That means the inverter system is more effective for meeting the heating load.

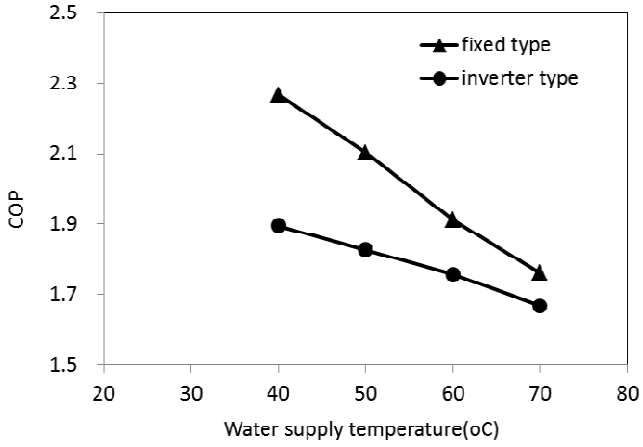


Fig. 4 Comparison of COP in each system with water inlet temperature (outdoor -15℃)

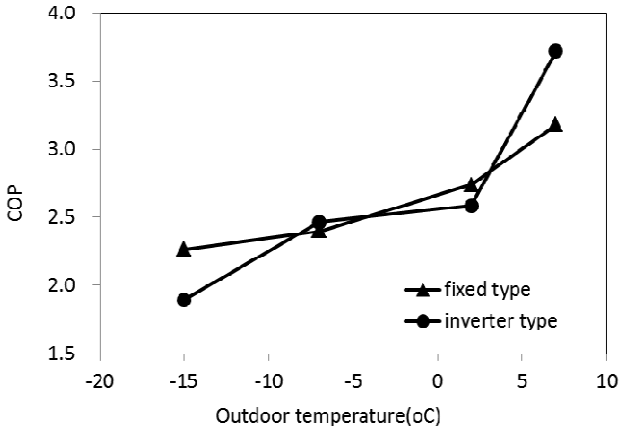


Fig. 5 Comparison of COP in each system with outdoor temperature (water inlet 40℃)

SCOP_C, which is SCOP in cold region and standard value in KSCOP, has weighting value of 39% in −7℃ and 2/1℃. Therefore it is very important to enhance COP in these temperature conditions. As shown in Fig. 6, considering same rate of increase in COP, it is positive to increase COP in 2/1℃ condition for improvement of SCOP_C in which condition COP is large. In order to understand the sensitive effect on SCOP_C, it reduces electric power consumption at the same rate and the results are examined. The reduction of power consumption can be similar result to increase of COP. Figure 7 shows such a result by 10% increase of COP in C1 to C10 of Table 2. From the results, it is realized that the values in C8, C9, C10 have much more effect on SCOP.

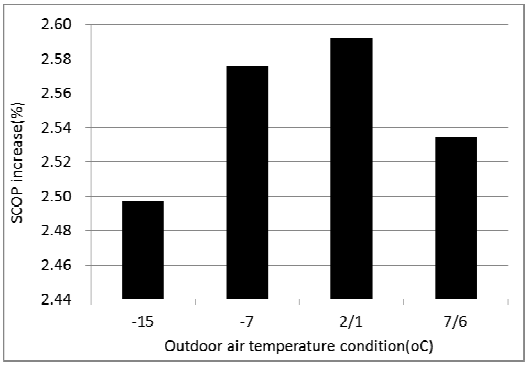


Fig. 6 Effect of COP in outdoor air temperature condition on SCOP_C

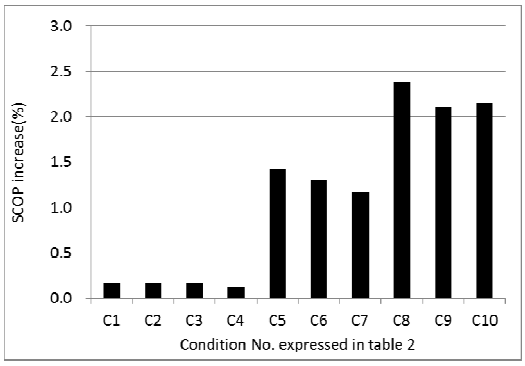


Fig. 7 Effect of COP in water/air temperature condition on SCOP_C

3. LOAD SIMULATION USING TRNSYS

In order to investigate the behavior of two systems, fixed type and inverter type, the simulation is conducted by using Trnsys software as shown in fig.8. Outdoor temperature is red line (left axis is temperature) which changes around 0℃. Green line means power consumption which is heating rate (right axis which is not displayed). Analysis object region is simple square room with walls and window. The results pointed out that inverter system can meet the heating load in a small heating rate. It means that less electric power is consumed to operate the system efficiently.

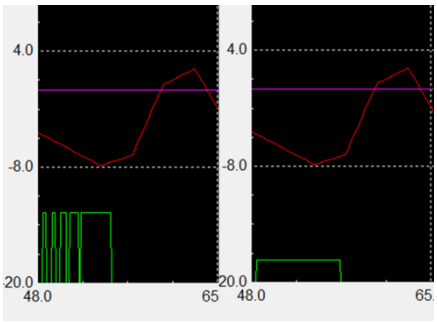


Fig. 8 Comparison of fixed type and inverter type system in a room under heating load

4. CONCLUSIONS

In this study, a fixed speed compressor type and an inverter compressor type system for hot water supply heat storage heat pump are compared and analyzed. The test conditions are based on KSCOP test conditions, and the heating capacity and COP of heating load are compared. In addition, the sensitivity analysis is conducted. Since the fixed type system is optimized at –15℃ ambient temperature, it is very advantageous at low ambient temperature though its electric power consumption is worse since the capacity is excessive. On the other hand, the inverter system can adjust its capacity corresponding to the various heating load which is to be advantageous for COP. The ambient temperature, 2/1℃ is most sensitive condition in SCOP. That means the system needs to be optimized in this condition. In addition, by using Trnsys software, simulation about heating load is conducted. The inverter system can be operated efficiently compared with fixed type sytem.

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