Next-Generation Gas Driven Air-Conditioning System Under the Condition of the Higher Setting Temperature of the Room in the Cooling Mode and Higher Ventilation

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ABSTRACT

In this paper, new air conditioning system in which only one desiccant rotor is connected to the vapor compression type refrigerator that is driven by the gas engine is suggested. And the performance of this system is evaluated by the simulation.
The feasibility of this suggested system is as follows.
(1) This system is so simple one that is a composed of the vapor compression type refrigerator and only one desiccant rotor.
(2) The vapor compression type refrigerator only cools the sensible heat and needs not dehumidifying the air so that COP is enhanced greatly by increasing the evaporating temperature.
(3) Two-stage regeneration is carried out. From this, the regeneration temperature of the desiccant rotor can be decreased greatly.
As a result, the regeneration temperature of the desiccant rotor is only about 40ºC at the condition of the room air temperature 28ºC. And COP of this system is about 20% higher than that of the conventional compression type refrigerator.

1. INTRODUCTION

To realize energy savings, the higher setting temperature of the room in the cooling mode of the air conditioner and air tightness of the building is demanded. On the other hand, suitable ventilation is needed against the sick house syndromes contrary to air tightness. The higher setting temperature and ventilation cause the increase in relative humidity in the room so that amenity in the room is getting lost.
Therefore, the new air conditioning system is expected to be developed for the next generation air conditioning in which the higher setting temperature and ventilation is needed.
In the conventional air conditioning system, dehumidification is conducted in the evaporator. In this way, because reheat is needed, performance is decreased when latent heat increases. Therefore the control system in which cooling and dehumidification is carried out independently is expected to be constructed.
Jeong et al. (2002) analyzed the hybrid air conditioning system composed of the compression type refrigerator and the desiccant air conditioning system. This system can realize higher performance, but the system is so complicated that the simplification of the system is demanded.

In this paper, low cost, higher performance air conditioning system with dehumidification is suggested.
For example, new air conditioning system composed of the compression type refrigerator and desiccant dehumidifier is suggested. This system is supposed to be driven by waste heat and motive power from the gas engine, and motive power is used for the compressor and waste heat for the regeneration of the desiccant. The performance is evaluated for the system with the simulation.

2. CONVENTIONAL AND SUGGESTED AIR CONDITIONING SYSTEM

In this paper, new air conditioning system composed of the compression type refrigerator and desiccant dehumidifier is suggested. In Fig. 1, the suggested air conditioning system is shown.
Jeong et al. (2002) have suggested the hybrid air conditioning system consisted of the compression type refrigerator and the desiccant air conditioning system as shown in Fig. 2. The compression type refrigerator is composed of the evaporator, condenser, compressor, expansion valve. The desiccant air conditioning system is composed of the desiccant rotor, sensible heat exchanger and two evaporative cooler. This system can use not only the motive power but also the waste heat from the gas engine so that the system performance becomes so high, but the cost

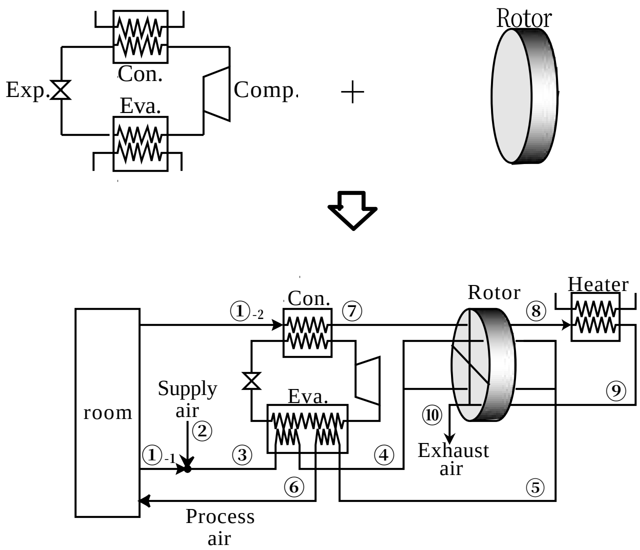

Figure 1 : Air condtioning system suggested in this paper

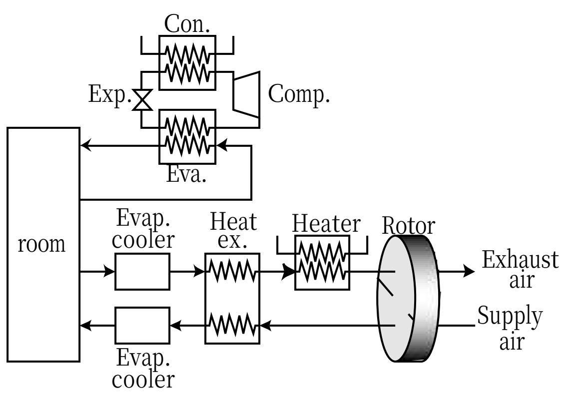

Figure 2 : Conventional hybrid desiccant air conditioning system

of the system also is getting higher. And water supply for the system is needed.

On the other hand, the suggested air conditioning system is composed of the compression type refrigerator and only one desiccant rotor so that the system is so simplified.

As shown in Fig. 1, the flow of the suggested air conditioning system is explained. In Fig. 3, driving points are shown on the psychrometric chart. In this system, the air flowing from the room is first mixed with the ventilation air and then this process air is cooled by the vapor compression type refrigerator. It is supplied for two parts of the desiccant rotor that is divided into four parts and dehumidified by the desiccant. Furthermore, this air is cooled by the vapor compression type refrigerator once again and then, provided for the room.

The regeneration air flowing from the room is heated by the waste heat and then dried the desiccant rotor. This air is heated by the waste heat and dried one part of the desiccant rotor once again and exhausted.

The feasibility of the suggested system is as follows.

(1) This system is so simple one that is composed of the vapor compression type refrigerator and only one desiccant rotor.

(2) The vapor compression type refrigerator only cools the sensible heat and needs not dehumidifying the air so that COP is enhanced greatly by raising the evaporating temperature.

(3) Two-stage regeneration is carried out and the process air is dehumidified by the desiccant rotor after cooled by the compression type refrigerator. From these, the regeneration temperature of the desiccant rotor can be decreased greatly.

(4) Higher performance dehumidifying operation can be realized because the reheat is not needed.

To evaluate the performance of the suggested air conditioning system, the performance is compared with the conventional air conditioning system as shown in Fig. 4,5. In the conventional air conditioning system, the air flowing from the room is mixed with the ventilation air and then this process air is cooled and dehumidified in the

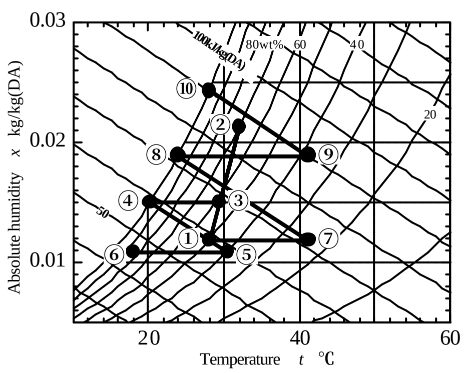

Figure 3 : Suggested air conditioning system on psychrometric chart

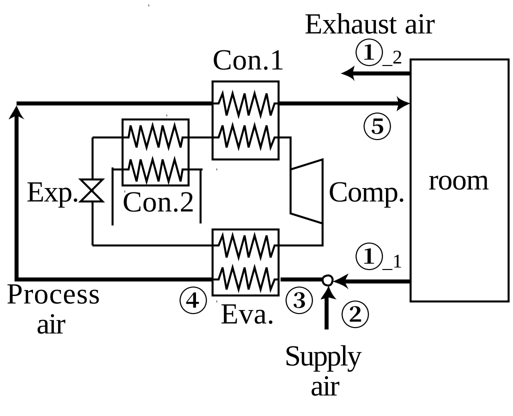

Figure 4 : Convetional air condtioning system

evaporator. Next, it is reheated in the condenser and provided for the room. The air whose amount is equal to that of the supplied air is exhausted.

3. SIMULATION MODEL AND CONDITION

3.1 Assumptions

(1) There is not pressure drop in the evaporator and condenser of the compression type refrigerator.
(2) There is not superheat area in the outlet of the refrigerant in the evaporator.
(3) The air is changed on the iso-enthalpic line in the desiccant rotor.
(4) The outlet relative humidity of the air in the adsorption and desorption part of the desiccant do not exceed the inlet one of the air in the desorption and adsorption part respectively.

3.2 Model of compression type refrigerator

The simulation model of the compression type refrigerator is shown in Fig. 6.
The motive power for the compressor is as follows.

$$W = G_R (h_{R2} - h_{R1}) \tag{1}$$

Outlet enthalpy is obtained from the following equation of adiabatic efficiency.

$$h = \frac{h_{R2rev} - h_{R1}}{h_{R2} - h_{R1}} \tag{2}$$

Heat rejection in the condenser is,

$$Q_C = G_R (h_{R2} - h_{R3}) \tag{3}$$

Iso-enthalpic change is assumed in the expansion valve.

$$h_{R3} = h_{R4} \tag{4}$$

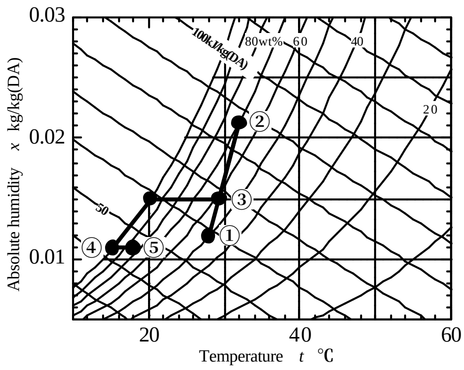

Figure 5 : Conventional air conditioning system on psychrometric chart

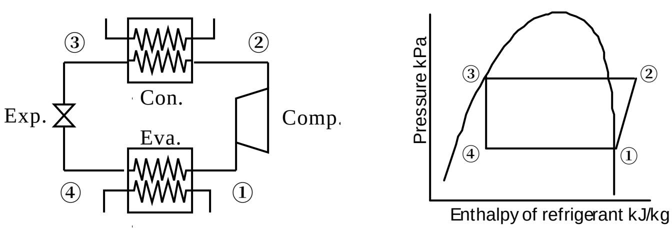

Figure 6 : Vapor compression type refrigerator

Heat flow rate of the evaporator is obtained as follows.

$$Q_E = G_R(h_{R1} - h_{R4}) \quad (5)$$

3.3 Model of desiccant rotor

As shown in Fig. 7, iso-enthalpic change of the air is assumed in the desorption and adsorption part so that the following equations are derived.

$$h_{A1} = h_{A2} \quad (6)$$

$$h_{A3} = h_{A4} \quad (7)$$

Water adosrbed in the adsorption part is equal to that desorbed in the desorption part.

$$G_{A12}(x_{A1} - x_{A2}) = G_{A34}(x_{A3} - x_{A4}) \quad (8)$$

The state of the air in the desorption and adsorption part is decided at the point that the relative humidity of point 1 agrees with that of point 4 or that of point 2 agrees with that of point 3.

3.4 Calculating conditions

The simulation is conducted based on the following conditions for the evaluation of the performance of the conventional and suggested air conditioning system.

(1) The setting temperature of the room is 28 °C, and relative humidity is 50 %

(2) The inlet process air for the room is 18 °C and SHF in the room is 0.8.

(3) The ventilation air flow rate is 33% of the process air for the room.

(4) The temperature of the ambient air is 32 °C and relative humidity is 70%.

(5) The working fluid of the compression type refrigerator is ammonia. The condensing temperatures of the refrigerant is 45 °C and the evaporating temperature is 5 °C lower than that of the process air supplied for the room. Adiabatic efficiency of the compressor is 70%.

4. EVALUATION OF SYSTEM

For example, in the conventional air conditioning system as shown in Fig. 4,5, the heat that the compression type refrigerator cools is ③〜④ , but the heat with which the room is actually cooled is ⑤〜① . Therefore in this paper, the cooling heat that is actually used to cool the room per motive power to drive the compressor is defined as COP. This COP is different from that is normally used.

5. SIMULATION RESULTS

5.1 Psychrometric chart of conventional air conditioning system

In Fig. 5, Simulation result of the base point is shown on psychrometric chart. For the conventional air conditioning system, COP is decreased because of the the reheat and decrease in the evaporating temperature needed for

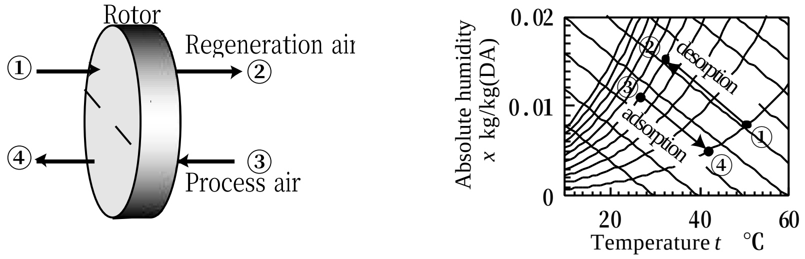

Figure 7 : Desiccant rotor

the dehumidification in the evaporator. Therefore COP is about 2.6.

5.2 Effect of ventilation air flow rate on conventional air conditioning system

Effect of increase in ventilation air flow rate on the conventional air conditioning system is shown in Fig. 8. From this, increase in the ventilation air flow rate leads to the great decrease in COP.

5.3 Effect of SHF on conventional air conditioning system

Effect of SHF on the conventional air conditioning system is shown in Fig. 9. SHF is changed by changing the reheat - ⑤ is changed- in Fig. 4,5. Decrease in SHF leads to the great decrease in COP because the reheat is increased so that the cooling capacity in the room is decreased.

5.4 Psychrometric chart of suggested air conditioning system

In Fig. 3, simulation result of the base point for the suggested air conditioning system is shown on the psychrometric chart. Characteristic of this system is that the regeneration temperature is 40 °C, though 50 to 60 °C is needed for the convolutional desiccant air conditioning system. From this, waste heat from the compression type refrigerator can be used. COP of the suggested air conditioning system is about 3.2. This is 20 %higher than that of the conventional air conditioning system.

5.5 Effect of ventilation air flow rete for suggested air conditioning system

In Fig. 10, Effect of the ventilation air flow rate on the performance of the suggested air conditioning system is shown. COP decreases for the suggested air conditioning system, too. The regeneration temperature increases in case of the decrease as the ventilation air flow rate increases. Therefore, higher temperature heat source is needed

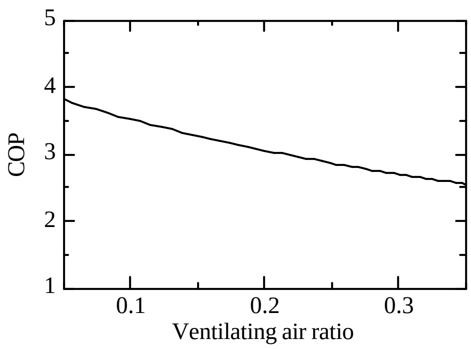

Figure 8 : Effect of ventilation on conventional air conditioning system

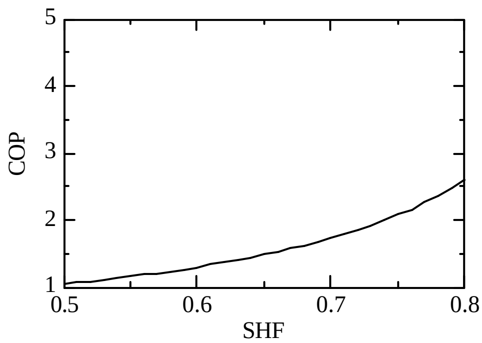

Figure 9 : Effect of SHF on conventional air conditioning system

if the ventilation is too small.

5.6 Effect of SHF on suggested air conditioning system

In Fig. 11, Effect of SHF on the suggested air conditioning system is shown. From this, COP does not decrease to the point of SHF 0.75. But when SHF decreases further, COP decreases a little. But the rate of the decrease is smaller than that of the conventional air conditioning system. In case of SHF 0.6, COP of the conventional air conditioning system is about 1.3. On the other hand, COP is 3.0 for the suggested air conditioning system. The reason is that in

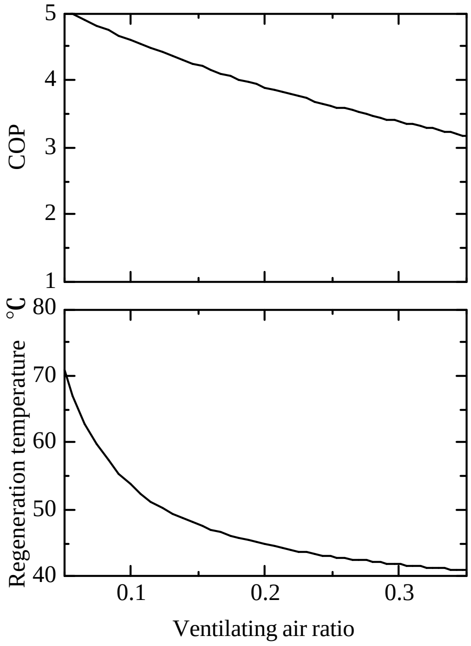

Figure 10 : Effect of ventilation on suggested air conditioning system

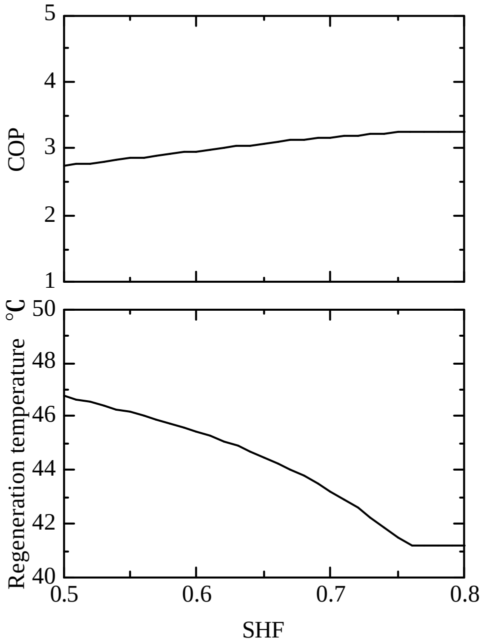

Figure 11 : Effect of SHF on suggested air conditioning system

the suggested air conditioning system, as the dehumidification in the evaporator is not needed, the evaporating temperature can be increased. The regeneration temperature slightly increases as the SHF decreases for the suggested air conditioning system. Therefore, it is necessary to have a little higher temperature heat sources.

6. CONCLUSIONS

This paper suggested the example of the next generation air conditioning system. This system can be realized with the simple system composed of the compression type refrigerator and only one desiccant rotor. The performance of this system is about 20 % higher than that of the conventional l air conditioning system and SHF can be changed without decrease in COP. Other air conditioning system will be suggested near future.

NOMENCLATURE

G_A	mass flow rate of air	(kg D.A./s)
G_R	mass flow rate of refrigerant	(kg/s)
h_A	enthalpy of air	(kJ/kg D.A.)
h_R	enthalpy of refrigeranto	(kJ/kg)
Q	heat flow rate	(kW)
W	motive power	(kW)
x_A	absolute water conc.	(kg/kg D.A.)
h	adiabatic efficiency	(-)

Subscripts

rev	reversible
C	condenser
E	evaporator

REFERENCES

Jeong, J., Kiyoshi, S., et. al., 2002, *Performance analysis of hybrid desiccant air conditioning system*, Proc. of JSRAE Annual Conf., JSRAE, p.145-148 (In Japanese).