C_D VALUE OF COOLING SEASONAL PERFORMANCE FACTOR

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Abstract: In the air-conditioning system, it is demanded to improve the APF (Annual Performance Factor) that is defined in JIS standard. In the APF, C_D value is needed for calculation of CSPF (Cooling Seasonal Performance Factor). C_D value is constant to evaluate the performance degradation in small cooling load. This value affects the APF greatly. In the current situation, as this value is defined to be constant, the manufactures can't change this value to evaluate their product even though they develop the system whose part load performance is high. This obstructs the development of the higher performance systems in small cooling load. Therefore, we try to develop new method to evaluate part load efficiency.
In this study, as a first step, C_D value is actually evaluated, based on the simulation and experiment. As a result, the performance of the air conditioning system is changed greatly in the part load and C_D value is not constant according to the driving conditions and control method.

Key Words: APF, CSPF, C_D value, Compression type heat pump

1 INTRODUCTION

By JIS B 8616:2006[6], which states the evaluation method for the rated performance for package air conditioners, APF (Annual performance factor) is adopted. Thus, improvements for the real annual performance are needed. As for this APF, we wanted to calculate the CSPF (Cooling seasonal performance factor), COP of low load intermittent driving is calculated by C_D value. And it is constant 0.25. But the performance during intermittent driving is determined by the mutual interference between load characteristics and control strategy, and not by the performance during continuous driving. Thus it differs by each controlling method for intermittent driving. Furthermore, nowadays when it has become possible to control compressors evermore delicately, it is unsuitable to predict performances at low load and intermittent driving. And also, if we adapt this standard, we might miss our chances to improve performances.
For these reasons, we studied on the nonlinear characteristics of the package type air conditioner from both simulation and experiment.
As for the next step, in this study, we considered what kind of effects is caused when the controlling method for intermittent driving is changed in many ways. From doing this, we made it clear that it is unsuitable to regard C_D value to be constant and furthermore, we understood that there are still many ways to improve controlling methods for intermittent driving.

2 DEGRADATION COEFFICIENT :C_D

The efficiency of package air conditioners normally increases when the load is decreased during continuous driving. But when the load has become too low, the system switches to intermittent driving because of device limitations. Generally, it is said that efficiency during intermittent driving is lower than that of continuous driving. Thus, we need to express in some way how efficiency decrease by means of specification standards. At the moment, JIS states that efficiency during intermittent driving decrease by 25% to that of continuous driving and furthermore, to express this it states C_D value to be a constant 0.25.

3 SYSTEM

In this study, we assumed a package type air conditioner such as the one on Fig. 1. The components are heat exchangers, connecting tubes, expansion valves, a compressor, a four-way valve and an accumulator. Rated cooling capacity is 7.1kW and for refrigerant we used R410.

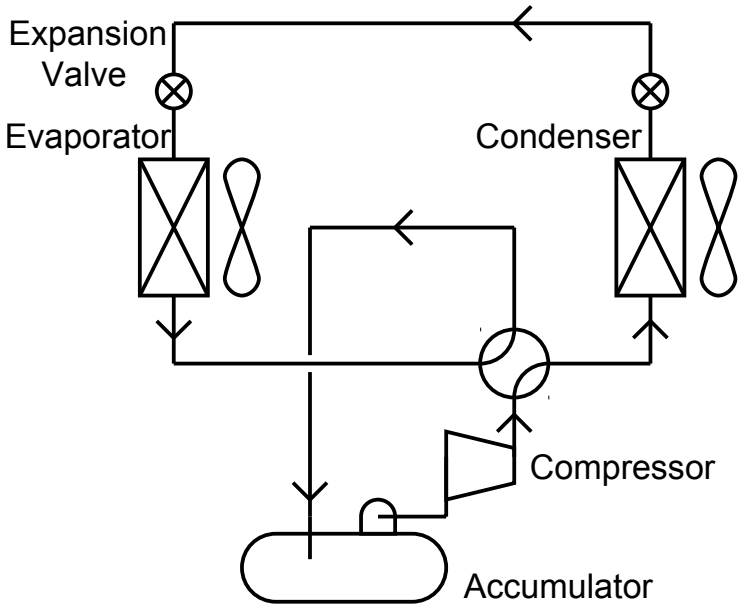


Figure 1:Package air conditioner

4 SIMULATION MODEL

For simulation model, we adopted the one we have been constructing [4][5]. This model analyses performances under very complex conditions such as intermittent driving, so we simplified our model by setting the heat transfer coefficient to be constant. Despite this simplifying process, our simulation results coincide with the experimental results as in Fig.2. Thus, we can say that our model has enough accuracy in evaluating intermittent driving performances [5].

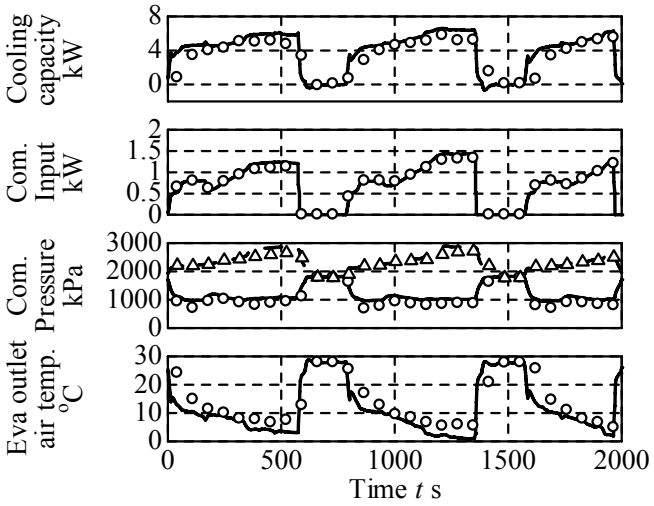


Figure 2:Validity of the simulation model

5 SIMULATION METHOD

For simulation model, we adopted the one we have been constructing [4][5]. This model analyses performances under very complex conditions such as off-and-on drive, so we simplified our model by setting the heat transfer coefficient to be constant. Despite this simplifying process, our simulation results coincide with the experimental results as in Fig.2. Thus, we can say that our model has enough accuracy in evaluating off-and-on drive performances [5].

6 EVALUATION METHOD

The cooling capacity for our system is the equivalent to transferred heat at the evaporator. So COP is defined as in Eq. (1). We obtained auxiliary input for this case from experiments. However in our research, we have to deal with COPs during intermittent driving. We can obtain this COP from integrated values of cooling capacity and system power input as in Eq. (2).

$$COP \equiv \frac{Q_{EVA}}{W_{COM} + W_{AUXS}} \tag{1}$$

$$COP \equiv \frac{\int_{start}^{end} Q_{EVA} dt}{\int_{start}^{end} \left(W_{COM} + W_{AUXS} \right) dt} \tag{2}$$

7 OPERATING METHOD OF INTERMITTENT DRIVING

In this research, we will consider the effects intermittent driving has on C_D value. The operating method for intermittent driving is as follows.

- We will adopt rotational speed of compressor for input and define it as rectangular waveforms.
- We will consider rotational speed of compressor during intermittent drive at 100%, 75%, 50%, and 25%, each compared to the rated value.

- Compressor driving time is 500 secs.
- We will consider indoor temperature to be controlled at around the aimed temperature by the air conditioner. For simulation, we consider indoor temperature to be 27°C constant.
- For loads, we will consider stand-alone shop by JIS. For this, load is 100% when the outdoor temperature is 35°C, and 0% when outdoor temperature is 21°C.
- Through intermittent driving, we will give one input per cycle for the compressor as in Fig.3. And, by adjusting the time to stop the compressor, we will adjust the load needed for a particular outdoor temperature.
- When compressor drive, outdoor airflow and indoor airflow are constant and they are taken from rated value. However in this case, we will consider that the auxiliaries would stop when the compressor is not driven.
- When the system becomes steady under the set outdoor temperature and compressor rotational speed, we will consider the expansion valve to open so that the super heat of evaporator outlet is 5°C and also, we will consider it to be a constant value.

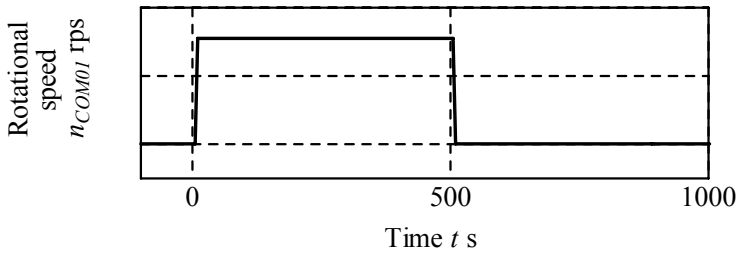


Figure 3:Simulation input (Compressor rotational speed)

8 RESULTS AND DISCUSSION

We ran a numeric analysis under the conditions we have been considering. The simulation results are shown on Fig.4~6. Fig.4 is the results for 100% compressor rotational speed. Fig. 5 is that of 75%, Fig.6 is that of 50%. The compressor driving time is 500 secs, and outdoor temperature is assumed to be 25°C.

From these results, performances increased as the compressor rotational speed decreased. Compressor input is defined by both the compressor rotational speed and the differential pressure to and fro it. For this reason, the condenser and the evaporator become larger relatively, the evaporating pressure increases and the condensing pressure decreases. Therefore compressor input decreases. So we can say that COP is likely to increase when compressor rotational speed is low.

But, by decreasing compressor rotational speed, evaporating pressure increases thus cooling temperature increases. For these reasons, problems such as decrease in dehumidifying performance, increased difficulty in recovering the lubricant oil which flowed out of the outdoor unit by flow rate decrease may occur. So we cannot say forcing compressor rotational speed to decrease is a good idea, but we can say that it is a way to restrain the amount of C_D.

We showed the comparison between our results and the COP by JIS on Fig.7. When the compressor is driven at 100% compared to rated rotational speed, COP was lower than that of JIS. When converted to C_D, it is about 0.4. When the compressor is driven at 75% compared to rated rotational speed, COP coincided very well with that of JIS. At 50%, COP was higher than that of JIS. When converted to C_D, it is about 0.1.

When compressor rotational speed was held down at 25%, C_D declined more and higher COP than that of JIS was examined. When converted to C_D, it is about 0.0.

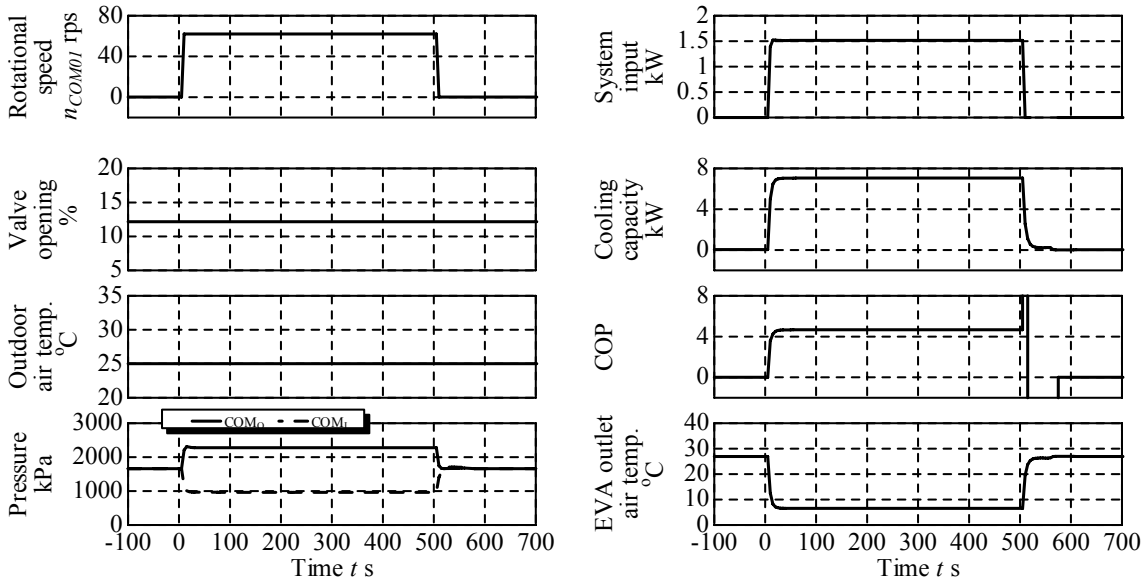


Figure 4:Simulation results (100%)

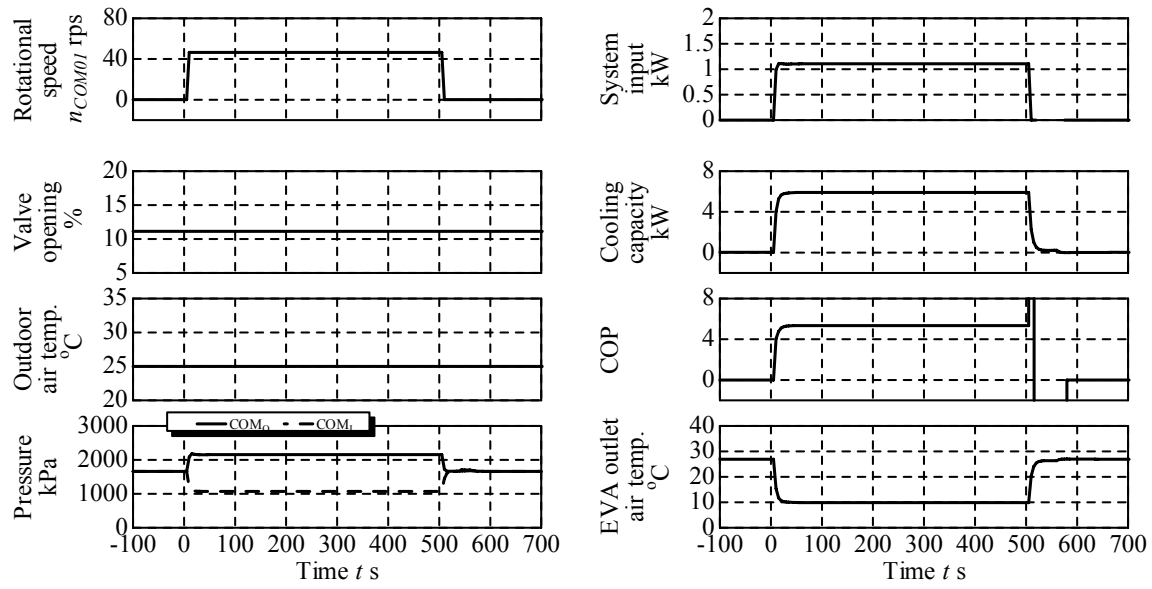


Figure 5: Simulation results (75%)

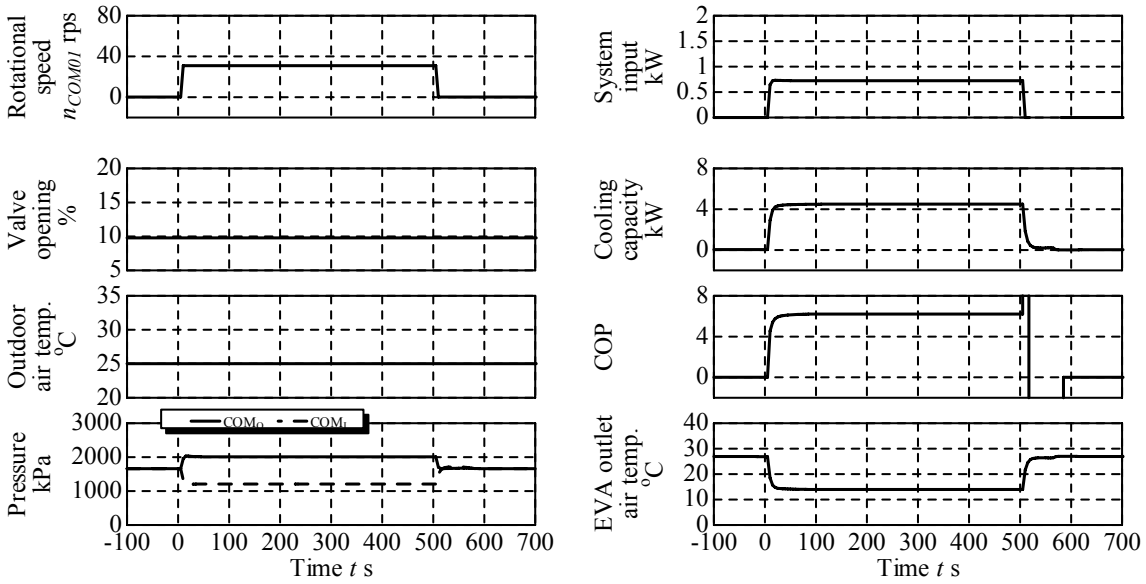


Figure 6: Simulation results (50%)

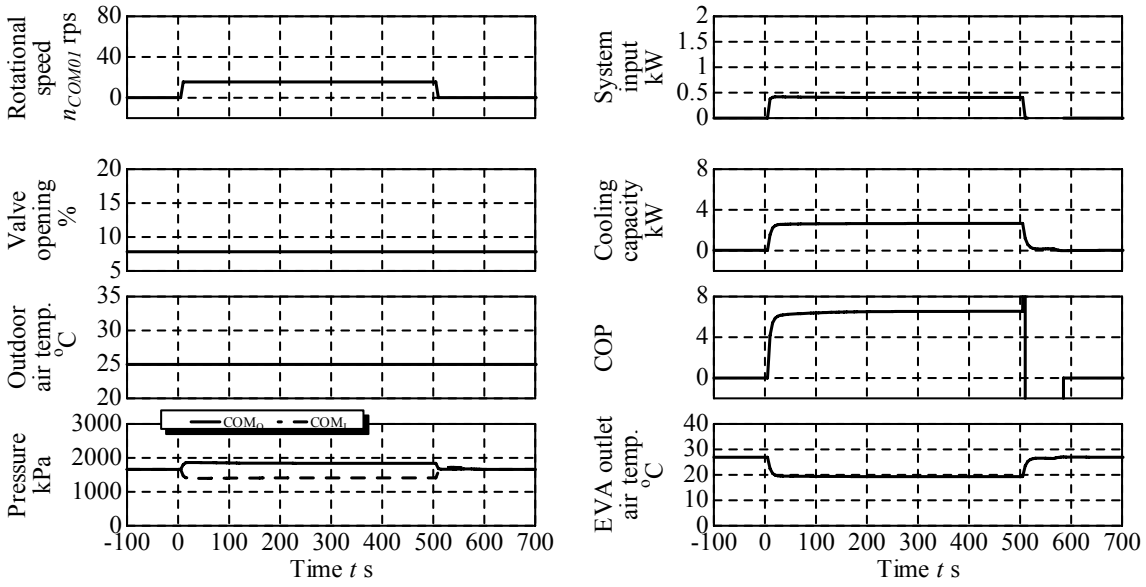


Figure 7: Simulation results (20%)

As a result, COP of air conditioner varies greatly when the compressor rotational speed is changed. Under the conditions of this research, C_D value ranged from 0.0 to 0.4. Air conditioners have a special controlling method for intermittent driving such as compressor control, super heat control and fan control. For these reasons, we assume COP increases in some conditions.

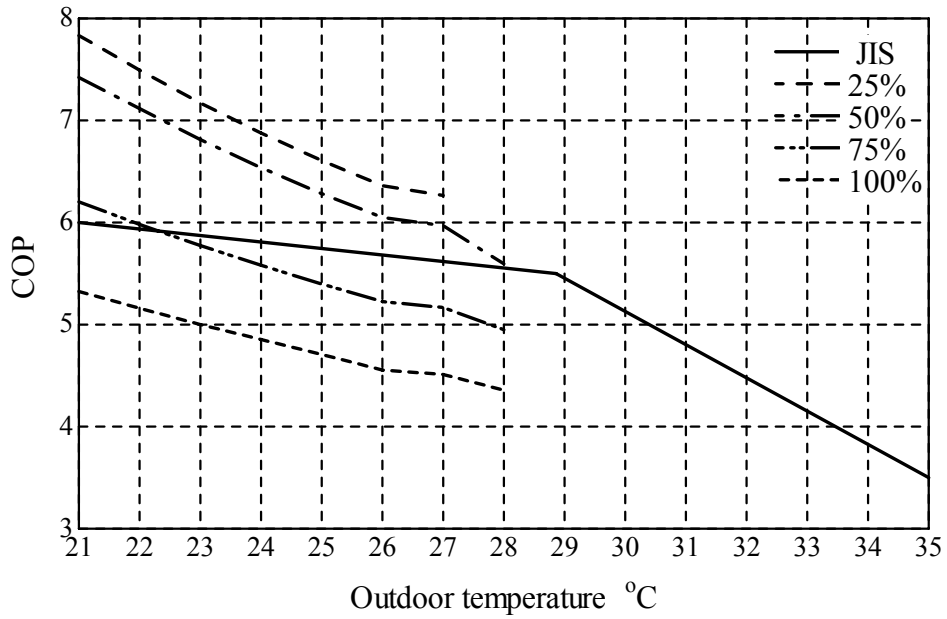


Figure 8:Package air conditioner

9 CONCLUSION

Aiming to confirm the reliability of the C_D value of CSPF for air conditioner JIS B 8616:2006, we mainly considered the effects compressor controlling has on C_D values by simulation. The results are stated as follows.

- COP differed widely under different compressor controlling methods. From our research, taking into account that C_D value ranged from 0.0 and up to 0.4, there was no validity in setting C_D to be a constant 0.25.
- When compressor rotational speed is low during intermittent driving, performance tend to increase (decrease in C_D), and when it is high, performance tend to decrease (increase in C_D).

For these reasons, when C_D is set constant, new devices with better performance during intermittent drive may be under estimated and thus developments for devices with better performance may be disturbed. To stop these interferences, we hope for revisions on standards in the future.

Furthermore, we have to take into account things such as oil circulation, human comfort issues like dehumidifying, and amount of load for driving actual devices. So we must consider optimum driving methods for package air conditioners with not just simulations but, also tests with actual devices.

10 NOMENCLATURE

COP : Coefficient of performance, -
n : Rotational speed, rps
Q : Heat exchange rate, kW
T : Temperature, °C
t : Time, s
W : Work, kW

11 SUBSCRIPTION

AUXS : Auxiliaries
COM : Compressor
EVA : Evaporator

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