Experimental performance studies of small wall room air conditioner for R410A retrofitted with R290

Berkah Fajar TK.[1*] *and Geraldus* Nicolas Dipto I.[2,*]

[1]Department of Mechanical Engineering, Diponegoro University, Prof.Sudharto, SH. Street, Tembalang-Semarang 50275, Indonesia
[2]Department of Mechanical Engineering, Diponegoro University, Prof.Sudharto, SH. Street, Tembalang-Semarang 50275,. Indonesia

Abstract. An original R410A wall room air conditioner was retrofitted with R290 for performance experiments. The R410A wall room air conditioner has a COP and a refrigerating capacity 6.0597and 1929.3 W respectively. In this study, the compressor R410A wall room air conditioner compressor was replaced with an R22 which is compatible. Mass R290 charged into the wall room air conditioner was 33.88%, 38.12% and 42.35%. Refrigerating capacity obtained was 1837 W, 1848.2 W and 2008.4W, while the COP was 5.2014, 5.0294, and 5.3275. The results obtained the R410A wall room air conditioner performance better than if the air conditioning machine retrofitted with R290.

1 Introduction

Chlorofluorocarbons (CFCs) and hydrochlorocarbons (HCFCs) can affect both stratospheric ozone and climate change, whereas hydrocarbons (HFCs) can affect climate change [1]. Therefore, it is important to raise awareness about preserving the ozone layer. In 1981 UNEP (*United Nations Environment Programme*) started negotiating over international measures to prevent ozone layer depletion through Vienna Convention. This convention creates efforts to preserve the well-being of human kind and the environment from the effects of ozone layer depletion, promotes cooperation on international research, observes ozone layer condition, and exchanges information regarding the matter. Then, in September 1987, Vienna convention is followed with the ratification of Montreal Protocol which contains regulation monitoring production, consumption, and trading of ODS (Ozone Depleting Substance) [2].

Mao-Gang He and associates study theoretically and experimentally for propane and its mixture as a replacement for R134a which was used in a large capacity chest freezer. Theoretically, R290 is 87.7% and 54.2% higher than R134a in terms of the mass and volumetric refrigerating capacities, while R290/R600a mixture (90/10 wt%) is 48.3% and 2.4% higher than R134a in terms of the volumetric refrigerating capacity and COP. The experimental test shows power consumption of R290 is 26.7% lower than R134a and the obtained optimal mass ratio from R290/R600a mixture is 93.75/6.25 wt% with 27.5%

*Corresponding author: fajarberkah10@gmail.com

lower in terms of power consumption than R134a [3]. In Marco Bortolini and associates research about the performance of retrofit process R404a with R410A and R407f in a refrigerating system which the expected result shows that R410A and R407f could substitute R404a. It is observed that moderate temperatures (-5; -10 C) R407f and R410A can achieve higher COP and refrigerating capacity than R404a which R407f has higher refrigerating capacity. However the COP is lower than R410A [4]. According to M. Mohanraj and associates research about R290/R600a mixture with mass ratio of 45.2:54.8 compare to R134a in domestic refrigerator with single evaporator and variation of ambient temperature namely 24, 28, 32, 38, and 43°C, is obtained which propane mixture has 11.1%, 11.6% and 13.2% lower power consumption and 3.25-3.6% higher COP based on pull down and on time ratio [5]. C. S. Choudhari and S. N. Sapali are also conducting research on analytical possibility to substitute R22 with R290 with the application of standard vapor compression cycle of evaporation temperature ranging from 25°C - 10°C and condensation temperature of 45°C which refer the analytical calculation. REFPROP 9.0 is utilized to obtain COP of R290 which is lower than R22, however the COP is expected to be higher by developing certain system design that compatible with R290 characteristics [6]. Referring to previous references, current research aims to study phenomena that occur by comparing the performances of R410A-charged split-type air conditioner with R290 where both R290 mass variations are analyzed to determine its optimal charging mass in order to achieve the same performance as R410A. This retrofit process is expected to be considered as one of the efforts to substitute R410A into R290.

2 Experimental Setting and Procedure

2.1 Experimental Setting

The experimental apparatus consists of one unit of split-type AC with 5000 BTU rated cooling capacity, data acquisition device, and measurement instruments, namely pressure gauges, temperature sensors (lm35), and a digital scale. The experiment starts with 340 grams of R410A (in accordance with the AC's name plate). After all the data from R410A have been recorded by data acquisition, various mass of R290 were charged into the system which were 21,18%, 25,41%, 29,65%, 33,88%, 38,12%, and 42,35% based on total mass of R410A on the name plate. Changing the default compressor into R22 compressors is considered in this experiment because of previous research by Sutandi shows that R22 compressor is compatible to R290 [7]. Each variation is measured for 90 minutes with 2 minutes interval for each measured data. Measurement starts along with the system starts and stops after the system reaches a steady state. Last variation involves changing the current compressor with default compressor (R410A) then charge the system with R290 based on condenser pressure of 270 PSI.

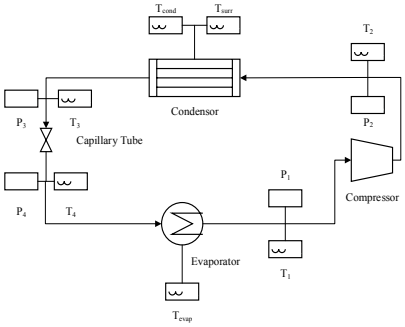

Figure 1. Schematic diagram of the experiment

From figure 1, the test apparatus and its measuring instruments are shown to illustrate the experiment. The following details describe each measuring instruments and their position:

1. One temperature sensor, LM35, is located where low temperature of air flows from evaporator (illustrated as T_{evap}) and the other are located after the refrigerant absorbed heat and pass through the evaporator. One pressure gauge is also located after the refrigerant pass through evaporator (illustrated as T_1 and P_1).
2. One temperature sensor, LM35, along with one pressure gauge is located at the outlet side where the refrigerant is compressed by the compressor (illustrated as T_2 and $P_{2)}$.
3. One temperature sensor, LM35, is located at the outlet of air flow from the condenser and the other one is located little distance away to measure the ambient temperature.
4. Two temperature sensors, LM35, and two pressures gauges are located at the inlet and outlet side of the capillary tube (illustrated as T3, P3, T4, and P4).

2.2 Experimental Procedure

After adjusting and setting the measurement devices, assembly process is conducted and leak test is also conducted on the testing apparatus afterward. If a leak is not detected, the system will be charged with R410A which its mass is adjusted according to its name plate. Re-checking the AC after conducting the test is mandatory so the system can perform normally. Then R290 with all its variations are charged into the AC gradually and are followed by replacing R410A compressor with R22/R290 compressor. The charged mass of R290 is measured with a digital scale by means of placing the refrigerant tank on top of the digital scale. Various variations, namely 21,18%, 25,41%, 29,65%, 33,88%, 38,12%, and 42,35% is obtained by adjusting and converting some variations that have been obtained and analyzed by Sutandi's research [6]. Before operating the system, always do a leak test first, then the experiment is ready. After collecting all data from various variations and default system, all those data are analyzed using Refprop to determine the enthalpy of each component.

3 Equation

A refrigerating effect is a difference of enthalpy on the outlet and inlet side of evaporator. The refrigerating effect can be calculated as following:

$$\frac{\dot{Q}}{\dot{m}} = h_1 - h_4 \tag{1}$$

While the work of the compressor can be calculated as follows:

$$\frac{\dot{W}_C}{\dot{m}} = h_2 - h_1 \tag{2}$$

Heat transfer rate per unit mass in condensor is total heat that is rejected by the condensor onto the surrounding per unit mass of refrigerant flowing.

$$\frac{\dot{Q}_{out}}{\dot{m}} = h_2 - h_3 \tag{3}$$

Efficiency of an air conditioner can be expressed by Coefficient of Performance (COP or β). It can be stated as the ratio between refrigerating capacity and work of the compressor.

$$\beta = \frac{\dot{Q}_{in}/\dot{m}}{\dot{W}_C/\dot{m}} = \frac{h_1 - h_4}{h_2 - h_1} \quad (4)$$

4 Results and Analysis

4.1 Refrigerating Capacity

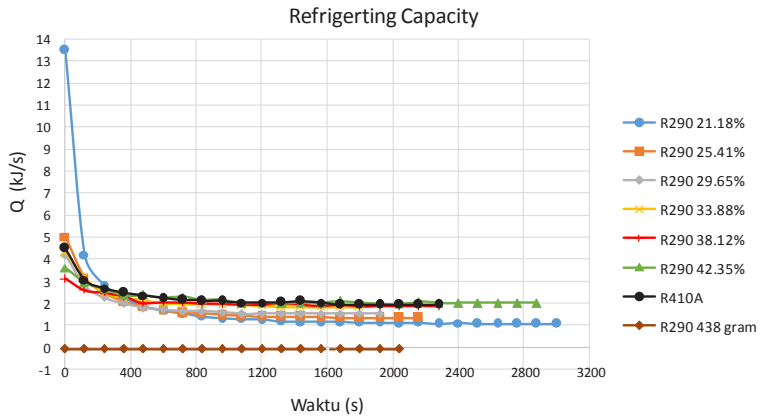

Figure 2. Graphic of refrigerating capacity of the evaporator in split-type air conditioner

From figure 2 above, it can be observed that the highest value of refrigerating capacity in steady state is resulted from 42.35% mass of R290 which has the value of 2.0084 kJ/s, while the lowest value of refrigerating capacity is resulted from 438 grams of R290 mass with an amount of -0.0831 kJ/s. It can be seen from the graphic above that the refrigerating capacity slowly declined over time. This phenomenon happens because the enthalpy from the outlet side of evaporator keeps declining, however the enthalpy on the inlet side keeps inclining over time. R410A has lower refrigerating effect, about 178.64 kJ/kg, than all variants of R290 mass which have values from 311.32 to 333 kJ/kg (except for R290 438 grams), however R410's value of refrigerating capacity has an amount of 1.929 kJ/s, slightly lower than R290 mass of 42.35%. This phenomenon is caused by the value of R410A mass flow rate which is considered to be the highest mass flow rate among all R290 mass variants with a value of 0.0108 kg/s. Therefore in terms of refrigerating capacity mass variations of R290 that can equal R410's refrigerating capacity are R290 33.88%, 38.12%, and 42.35%.

4.2 Compressor Power Consumption

From the figure 3, the highest value of compressor power consumption is achieved by R290 42.35% mass variation with an amount of 0.377 kJ/s, while the lowest value is achieved by R290 21.18% mass variation with an amount of 0.312 kJ/s.

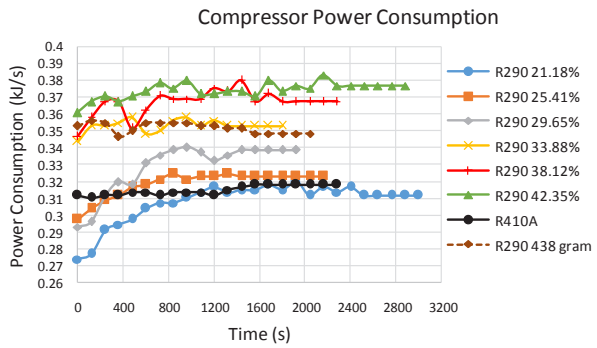

Figure 3. Graphic of compressor power consumption in split-type air conditioner

Each variation has similar trend which is gradually inclined then fluctuated over time (except for 438 grams of R290), due to the increased of enthalpy difference at the discharge and suction side of the compressor. R410A has relatively lower compressor work per unit of mass which has the value of 29.48 kJ/kg than the compressor work per unit mass of all R290 mass variants which have values from 59.51 to 96.48 kJ/kg. Even though the mass flow rate of R410A is considered to be the largest of all variants, R410A has lower compressor work per unit mass, hence the power consumption of R410A is also relatively low. Therefore in terms of compressor power consumption, the variants of R290 mass that can equal or even lower than the compressor power consumption of R410 are R290 21.18% and 25.41% which have the value of 0.312 kJ/s and 0.3231 kJ/s, respectively.

4.3 Coefficient of Perfomance

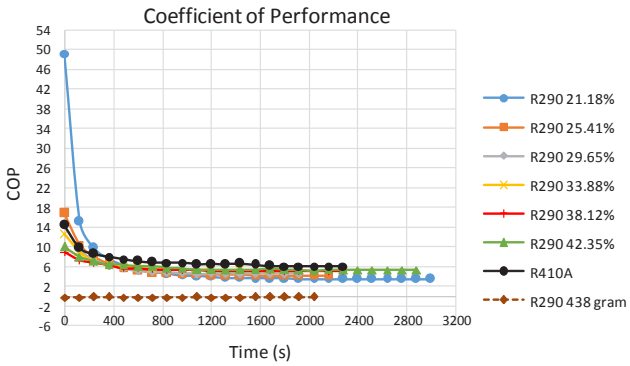

Figure 4. Graphic of coefficient of performance in split-type air conditioner *Split*

From the figure 4, it can be observed that the highest value of coefficient of performance in steady state is resulted from R410A as default system which has the value of 6,0597, while the lowest value of coefficient of performance is resulted from 438 grams of R290 mass which has the value of 0,23839. Each variation has a similar trend which is gradually inclined over time until a steady state is achieved. This phenomenon occurs due to the value of refrigerating effect per unit mass which gradually decrease over time, however the compressor work per unit mass gradually increases as well. Hence in terms of coefficient of performance, the variants of R290 mass that can equal or even lower than the R410A

performance are R290 33,88%, R290 38,12% and R290 42,35% with a value of 5,2014, 5,0294, and 5,3275, respectively.

5 Conclusions

1. The coefficient of performance (COP) obtained from R410A test has the value of 6.097 in a steady state while the refrigerating capacity and compressor power consumption have the value of 1.9293 kJ/s and 0.3183 kJ/s, respectively.
2. After retrofitting the air conditioner from R410A into R290 either with changing the R410A compressor with the compatible one or changing it back to R410 compressor, the result analysis shows that in steady state, R290 33,88%, 38,12%, and 42,35% have values of COP that close to the COP of R410A. Those values are 5.2014, 5.02940, and 5.3275, respectively. In terms of refrigerating capacity, the variations of R290 mass that can equal the performance of R410A are R290 33.88% with 1.8373 kJ/s, 38.12% with 1.8482 kJ/s, and 42.35% with 2.0084 kJ/s. From the compressor power consumption, it is observed that R290 21.18% with 0.3120 kJ/s and 25.41% with 0.3231 kJ/s are close to the result of R410A test. Therefore, experimenting on the air conditioner and conducting retrofit of R410A into R290 is proven to give effect on the air conditioner system in terms of COP, refrigerating capacity, compressor power consumption, and heating capacity.
3. After conducting various test of every variation of R290 mass, it can be concluded that the charged mass of 33.88% R290 shows that it can be considered to be used in retrofitting air conditioner from R410A into R290 even though its compressor power consumption is higher than R410A. Due to lower charged mass of R290, 33.88% is much safer than one with 38.12% or 42.35%.

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