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Experimental Study on the Performance of a R-22 Freezer Retrofitted with R-290

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Abstract

R-22 has a relatively high nature of global warming, the use of R-22 must be stopped. Refrigerant r290 / R290 is the type of refrigerant recommended by many experts to replace R-22 because the global warming properties of R-290 are much lower than R-22. In this research, cooling capacity, mass flow rate, the power consumed, and COP were evaluated. The freezer machine used has a capacity of 1 PK, redesigned by adding ducting to the condenser channel. Overall results, R290 can be a better substitute for the R22 in real applications due to excellent ambient, thermo-physical properties, and energy-saving performance.

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Keywords: R22; R290; mass flowrate; power consumption; COP; cooling capacity

1. Introduction

The vapor compression cycle is a cooling machine widely used today. Working fluids that are often used are synthetic refrigerants. In the 1930s until the mid-1970s, the impact of the use of synthetic refrigerants such as chlorofluorocarbon refrigerant (CFC) and hydro chloral fluorocarbon (HCFC-22) has not caused environmental problems. This is not to say that the use of refrigerants does not have a negative impact on the environment, but rather

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Nomenclature

ρ	density (kg/m^3)	W_c	energy consumption (kWh)
$\dot{m}$	mass flow rate (kg/s)	SW	sweep volume (m^3/s)
COP	coefficient of performance	Q_e	cooling capacity (kJ/s)
h	enthalpy (kJ/kg)	V	working voltage (volt)
T	temperature (^{o}C)	I	current flowing to load (Amp)
v	specific volume (m^3/kg)	Cos φ	power factor

on the limitations of knowledge and environmental awareness at that time. The use of synthetic refrigerants causes problems with the environment. Some refrigerants that originally considered ideal now considered dangerous so they must be replaced [1]. All companies are in the process of replacing CFCs with HCFCs and subsequently also replacing HCFC with HFC. Global warming, climate change and rising temperatures on average Earth's atmosphere become the main problem for the environment caused by HFCs and many other substances have the value of ozone depletion potential (ODP), these refrigerants have a higher global warming potential (GWP) value. New environmentally friendly refrigerants are needed and can save energy. For this reason, the researchers returned to use natural hydrocarbons such as Propane (R290) [2].

The government issued a program to reduce the impact of ODS (Substance Destructive Substances) on the ozone layer. One of them is the use of renewable refrigerants is an absolute necessity. The Montreal Protocol, which revised through the London 1990 amendments and revised again with the 1992 Copenhagen amendment, the use of CFC 12 and HCFC-22 in the world must be limited to further prohibition [3].

In the last decades, flammable hydrocarbon refrigerants banned in normal air conditioning and refrigeration applications due to security problems. R290 hydrocarbons identified as safe, odorless, colorless refrigerants that have excellent thermo-physical properties in 1920. However, after the development of CFCs and HCFCs in 1928, refrigerants ignored because they were flammable. With the changing scenario and current technological developments, the industry now seems more receptive to R290 as a potential substitute for R22 [4-8].

It is also hoped that the electricity consumption used would be more economical than before because MC-22 has different thermodynamic properties compared to refrigerant-22, which will also have an effect on the cooling effect obtained between the cooling system before and after changes in the type of refrigerant. Cooling system-cooling values was analyzed to get the system performance value. The environmental property including ozone depletion potential (ODP) and global warming potential (GWP) of some refrigerants can be found in previous reported literature [9-10]. Furthermore, the physical and thermo-physical property of R22 and R290 was reported [11].

2. Method and apparatus

The equipment used consisted of a compressor, a condenser, an evaporator, and a capillary pipe (Fig. 1). The main components of the freezer were separated from the configuration to obtain data performance on the compressor, condenser, and evaporator. These main components were separated from its configuration (freezer) to obtain data performance on compressor, condenser, and evaporator. Then the component was connected with the refrigerant piping. The temperature and pressure of each component were measured to determine the level of refrigerant. The mass flow rate of the refrigerant was measured by the refrigerant out of the compressor. In addition to pressure and temperature, the electrical current required by the compressor was also measured. The condenser and evaporator were in different positions, the condenser was placed inside the ducting and the compressor was placed in the freezer box. This measurement was designed to determine the performance of the freezer which consisted of: (i) mass flow rate, (ii) compressor power, (iii) a coefficient of performance, and (iv) cooling capacity.

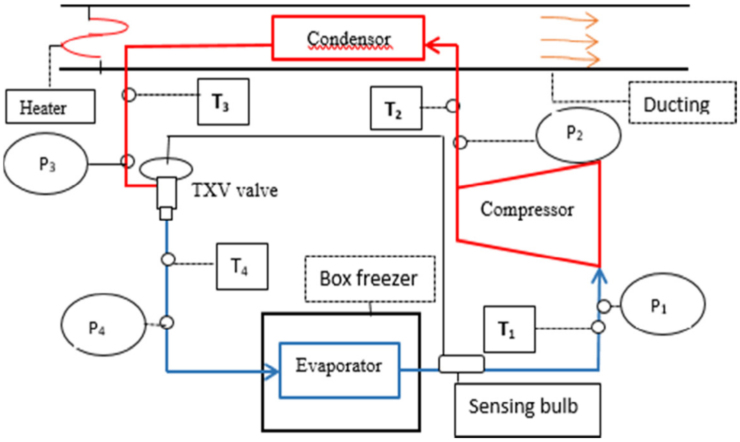

Fig. 1. Schematic Diagram

The cooling system in first vacuum used a vacuum pump before filling the refrigerant. Filling 450 g of R-22 on the outer signboard. After retrieving data using refrigerant R-22 then the vacuum pump was used again. Furthermore, the R-290 was used as much as 30%, 40%, 50% or with a mass of 135 g, 180 g, and 225 g. The enthalpy results of the experiment calculated by the compressor work with the following equations:

$$\dot{m} = \rho \; x \; SW \; x \; \eta v \quad (1)$$

Power Consumption calculated using the equation:

$$w = V. \; I \; .Cos \; \varphi \quad (2)$$

Steam compression machine efficiency expressed with the Coefficient of Performance (COP or β):

$$C = \frac{h_1 - h_4}{h_2 - h_1} \quad (3)$$

Cooling capacity calculated using the following formula:

$$Q = \; ? \; (h_1 - h_4) \quad (4)$$

3. Results and discussions

Retrofit/replacement of refrigerants directly carried out. No need to replace system components. The character and temperature of HC coolers are similar to synthetic coolants. Based on the results of the enthalpy values obtained from the study can calculate the mass flow rate, compressor power, COP, and cooling capacity. Fig. 2(a). shows the increase in mass flow rate is influenced by the temperature of the condenser air intake. A high temperature will cause the TXV valve to open wider and more refrigerant will flow. Thus, the volume swept changes as the amount of refrigerant is loaded into the cooling system and the temperature of the air entering the condenser.

Theoretically, increasing the temperature that enters the condenser has a large influence on the compressor's power. Fig. 2(b). shows the temperature of the air entering the condenser has an impact on the increasing electricity consumption. This is due to the compressor's work becomes large. The power used will also be higher. The mass of 30% showed the period of refrigerant entering the cooling system is less, so that the absorption of heat in the evaporator cannot be maximized.

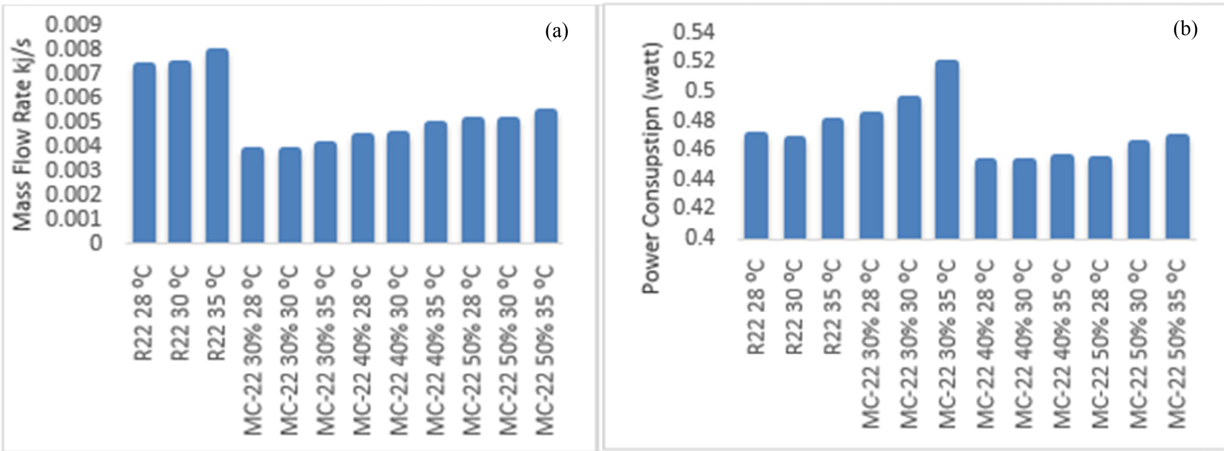

Fig. 2. (a) mass flow rates for variations in condenser inlet air temperature and refrigerant mass variations; (b) Compressor power on variations in condenser intake temperature and variations in mass of refrigerant

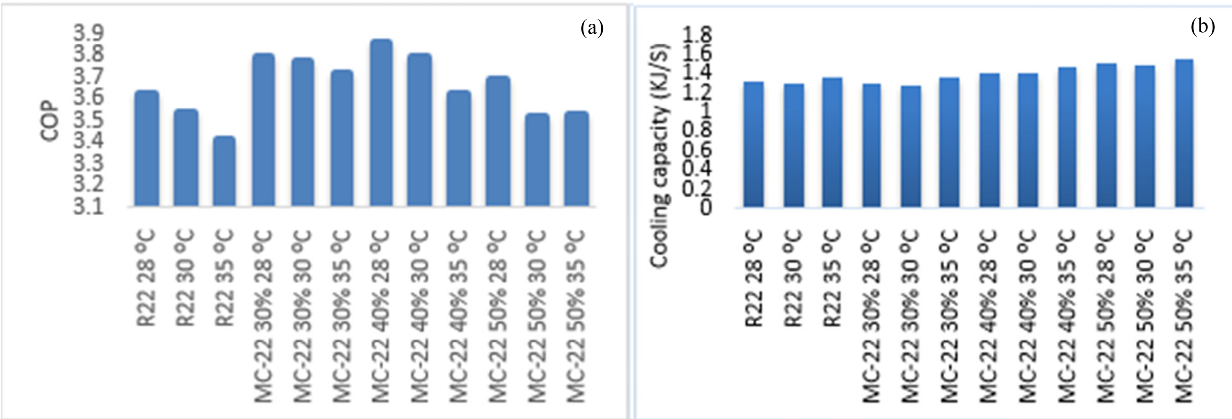

Fig. 3. (a) COP on variations in the temperature of the inlet air condenser and variations in the mass of the refrigerant; (b) Cooling capacity to variations in condenser air temperature and variations in mass of refrigerant.

The best COP occurs in HC 40% of filling refrigerants at the temperature of the air condenser 28ºC, which is 3.86. Fig. 3(a). shows if the temperature of the air entering the condenser is getting hotter the performance of the cooling system will decrease. The amount of the refrigerant inserted in the cooling system causes an increase in pressure, the temperature of the suction compressor changes this event, which results in a change in the mass flow rate of the refrigerant and the effect of the cooling system. Given the cooling capacity is the product of the cooling effect with the mass flow rate of the refrigerant. Fig. 3(b). provides an illustration of the effect of filling refrigerants on the cooling system.

4. Conclusion

The results of this study indicate that variation in mass and variation in filling in the freezer were mounted by R290 to R22. The mass flow rate produced by R290 is lower than R22. The coefficient of performance of R290 is higher than R22. The highest COP in this study is shown by R290 with a variation of 40% of the filling mass with an inlet air temperature of 28 ºC. Overall, the R290 can be a better substitute for the R22 in real applications because of its excellent ambient, thermo-physical properties, and energy-efficient performance.

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