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Performance of an Air Conditioning as Hybrid Refrigeration Machine Uses Hydrocarbons Refrigerant (HCR22) As Substitutes For Halogenated Refrigerant (R22)

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ABSTRACT

Hybrid refrigeration machine is the machine with refrigeration principle and heat pump in one machine, so-called the hybrid refrigeration vapor compression. Air-conditioning and refrigerating industries weathered the phase out of chlorofluorocarbons (CHCs) and hydro chlorofluorocarbons (HCFCs), which caused from the ozone layer depletion, by developments of hydro fluorocarbons (HFCs) as alternative refrigerants. However, the HFCs will also phase out because they are greenhouse gases as a cause of global warming. Therefore, natural substances, such as ammonia, hydrocarbons, carbon dioxide, are getting great interest. The research result is indicated that the use of mass HCR22 (hydrocarbon refrigerant of substitution R22) at hybrid refrigeration machine more economical 57.78% compared to R22 (halocarbon refrigerant), because HCR22 has the higher level of latent heat compared to R22. Cooling rate and heating rate by HCR22 compared to R22, is more efficient too. The Power consumption of compressor use of HCR22 is more economical 25.12% compared to hybrid refrigeration machine that use R22. In conclusion using of hydrocarbon refrigerant can economize of electrical energy consumption and environmental friendly.

Keywords

refrigeration, refrigerant, hybrid, hydrocarbon, halocarbon

1. INTRODUCTION

Refrigeration machine generally is used for conditioning room as cooling effect from evaporator that give comfortable and chilly sense for human in working room or office building, houses, apartment, industry, office, hospital, etc. Refrigeration machine is one of energy conversion machine type, where a number energy is needed to result refrigeration effect [1]. On the other side, heat losses waste by system goes to environment as requirement thermodynamics principle that machine can be function. Heat from the condenser escaped to environment usually castaway off hand without exploited. And so do at heat pump machine, a number of energy required to give the warming effect by absorbing heat from environment. Absorbing heat from the environment can be exploited to make cool something, but usually tend to let castaway[2].

Starting from case of refrigeration machine and heat pump machine above, hence various effort have been done to develop a system using principle of refrigeration and heat pump in one machine. At this machine, cooling effect and heating effect can be yielded and exploited simultaneously, so that useful power of machine becomes higher. Inwrought machine with the this double function is recognized as hybrid refrigeration machine, because refrigeration machine generally operating with the vapor compression cycle, hence this machine is referred as refrigeration machine vapor compression cycle [3].

To operate the refrigeration machine with hybrid vapor compression cycle is required the refrigerant as working fluid. The refrigerant usually used is the halogenated refrigerant; one of them is type HCFC-22 /Hydro chlorofluorocarbon or R-22. But from the result of research, halocarbon refrigerant show the nature of which can destroy the ozone layer and have big potency to make-up of global warms effect, so that the use refrigerant will be discontinued inclusive of also making and its usage [4].

One of alternative refrigerant for substitution of halocarbon refrigerant is hydrocarbon refrigerant. Some excess owned by the hydrocarbon refrigerant, that is serve the purpose of direct substitution (drop in substitute) without component replacement, environmental friendly (do not damaged the ozone layer), a little usage refrigerant, economize the energy, and fulfill the international standard [5].

This research aim to know the parameter influencing performance of air conditioning, what modification have become the hybrid refrigeration machine, among other things is cooling capacities, warming capacities, energy for compressor, coefficient of performance (COP) and performance factor (PF). This Research is done because exploiting of evaporator and condenser simultaneously of course will be give the trouble or change to influence the machine performance. At this research is used hydrocarbon refrigerant as replacement of halocarbon refrigerant (R-22). With hydrocarbon refrigerant, the air conditioning apparatus

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remain to admit of used without component replacement and expected do not go down the system performance.

2. RESEARCH METHOD

The refrigeration machine used in this research, is modification from air conditioning machine become the hybrid refrigeration machine. This apparatus, evaporator and condenser use water as cooling and heating load.

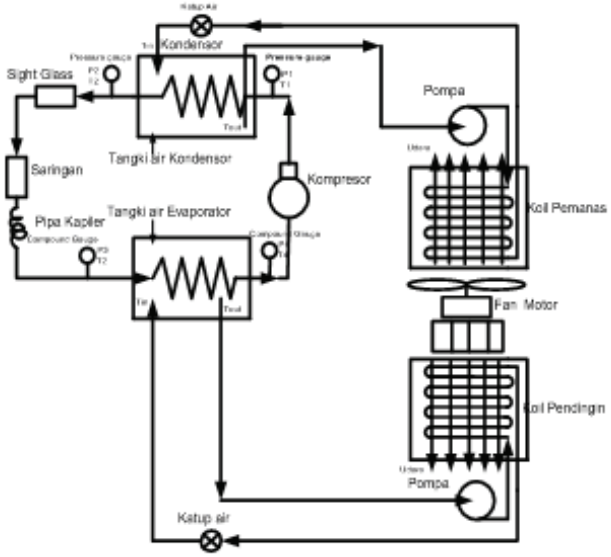

Figure 1: Simple scheme of hybrid refrigeration machine of vapor compression cyle.

Research method done through few step in the following is:

1. Phase of Research Preparation.

This step is done by literature study and understanding to concept of refrigeration machine of vapor compression cycles that using hydrocarbon as refrigerant, by learning book and relevant recent of research journal.

2. Phase of Design and Apparatus Making Test.

At this step is done design of test apparatus base on literature study or recent research journal publication. Furthermore, result of design is realized by doing equipment making test that is a refrigeration machine of vapor compression

3. Phase of Test Data Result

At this step is done data record that needed by using some kinds of measuring instrument for example: pressure gauge, thermometer, millimeter, stopwatch, etc. Data taken cover the power of compressor, temperature input and output from the evaporator, temperature input and output from the condenser, flow rate of water in to cooling and heating water tank, pressure input and output from the compressor, pressure of condenser and pressure of evaporator

4. Phase of Data Analysis

Data obtained will be tabulation and done calculation according to principles of thermodynamics, the data will be plotted in graphics which can give the information about influence of temperature input and output from evaporator, influence of temperature input and output from condenser, water flow rate from heating and cooling water tank, pressure input and output from compressor, pressure from condenser and evaporator, that compared to system performance.

5. Phase of expression about conclusion

At this step the entire result obtained from step 1 to step 4 previously concluded to become the final conclusion obtained from this research, and suggestion for the perfection of next research.

3. RESULT AND DISCUSSION

3.1 Result of Design the Hybrid Refrigeration Machine

The result of design the hybrid refrigeration machine is:

1. Compressor, in this machine used hermetic compressor, with rotary type, the power of compressor is 1 HP.
2. Evaporator, in evaporator used copper pipe 3/8 “, that have one pass with 31 cm long. The entire evaporator have 66 pass with 11 level. Each level have 6 pass. The design data from evaporator :
   a. Temperature of outer pipe surface, *Ts* is 9.17 ^oC
   b. Total surface area of pipe, *Ao* adalah 0.6175 m^2
   c. Lenght of pipe, *L* adalah 20.69 *m*
   d. Coefficient of mean heat transfer, h_0 = 219.018 $W/m^2.{}^0C$
   e. Overall heat transfer coefficient, U_0 = 172.7496 $W/m^2.{}^0C$
3. Condenser, in condenser used copper pipe 3/8”, that have one pass with 33 cm long. The entire evaporator have 66 pass with 11 level. Each level have 6 pass. The design data from evaporator :
   a. Temperature of outer pipe surface, *Ts* is 40.93 ^oC
   b. Total surface area of pipe, *Ao* adalah 0.6489 m^2
   c. Total Lenght of pipe, *L* adalah 21,74 *m*
   d. Coefficient of mean heat transfer, h_0 = 315.738 $W/m^2.{}^0C$
   e. Overall heat transfer coefficient, U_0 = 236.649 $W/m^2.{}^0C$
4. Capillary pipe, the diameter of capillary pipe is 1.7 mm, that working at condensation temperature 45 ^oC and evaporation pressure 5 ^oC, the lenght of capillary pipe is 1.65 m.

3.2 Data Processing of Test Result

Data obtained from testing through measurement is in the form of nature of from refrigerant, water, and electrics data. Nature of the among other things is temperature, pressure, mass, time, speed and also voltage and electrics current.

Calculation Sample:

Power of compressor:

$$W_k = \eta_m \times \sqrt{3} \times V \times I \times Cos\phi = 0.82 kW$$

Where: $\eta_m = 0.8$, $\cos\phi = 0.83$, $V = 223$ volt,

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I = 3.2 A

Cooling capacity in the evaporator box:

$$Q_e = \dot{m}_{ae} \times C_{P,ae} \times \Delta T_{ae} = 2.17kW$$

Where: $\dot{m}_{ae}$ = 0.1234 kg/s,

C_{Pae} = 4.183 kJ/ (kgK),

ΔT_{ae} = 4.2 °C

Heating capacity in condenser:

$$Q_k = \dot{m}_{ak} \times C_{P,ak} \times \Delta T_{ak} = 2.91kW$$

Where: $\dot{m}_{ak}$ = 0.0883 kg/s,

C_{Pak} = 4.178 J/ (kgK),

ΔT_{ak} = 7.9 °C

Coefficient of performance:

$$COP = \frac{\dot{Q}_e}{\dot{W}_k} = 2.64 \quad , \; PF = \frac{Q_k}{W_k} = 3.55$$

$$TP = \frac{(q_k + q_e)}{w_k} = 6.19$$

3.2 Discussion

At this research will be analyzed influence of water mass flow rate in evaporator water tank to performance of hybrid refrigeration machine (COP, PF and TP). Analyze also will learn about the water mass flow rate in evaporator to cooling effect, heating effect, and the power of compressor. Furthermore watch closely about change of water mass flow rate in evaporator/condenser to water temperature input and output, temperature and pressure in refrigeration machine

3.2.1 Mass of Refrigerant R22 and HCR22

Comparison of between amount of R22 refrigerant mass to HCR22 refrigerant (figure 2), the optimum mass of R22 is 900 gram at COP 2.42, while the optimum mass of HCR22 is 380 gram at COP 2.55. So the uses of HCR22 refrigerant, the refrigerant mass more efficient 57 percent to the mass of refrigerant R22.

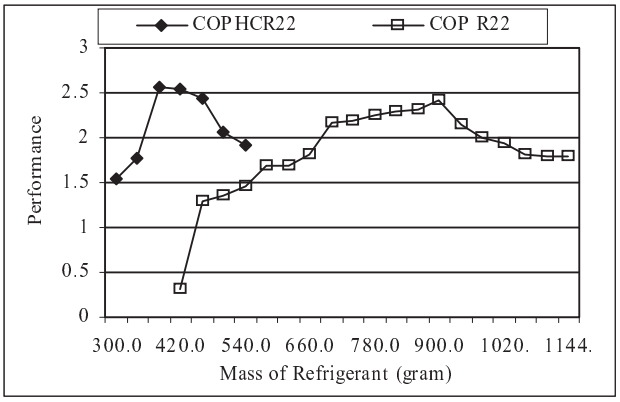


Figure 2: Optimum mass and optimum COP of refrigerant HCR22 and R22

3.2.2 Cooling Rate and Heating Rate

At transient condition that is condition of moment of hybrid refrigeration machine at first start run until steady condition, figure 3 shows that cooling rate of HCR 22 compared to faster than cooling rate of R22.

The cooling time until steady condition for HCR22 around 40 minutes at temperature 7.1 °C, whereas R22 need time around 60 minutes at temperature 8.3 °C. Heating rate until steady condition for HCR22 around 40 minutes at temperature 44.8 °C whereas R22 need time around 60 minutes at temperature 44.4 °C. Appear that cooling rate and heating rate for HCR22 faster than R22 with cooling time and heating time almost at the same period.

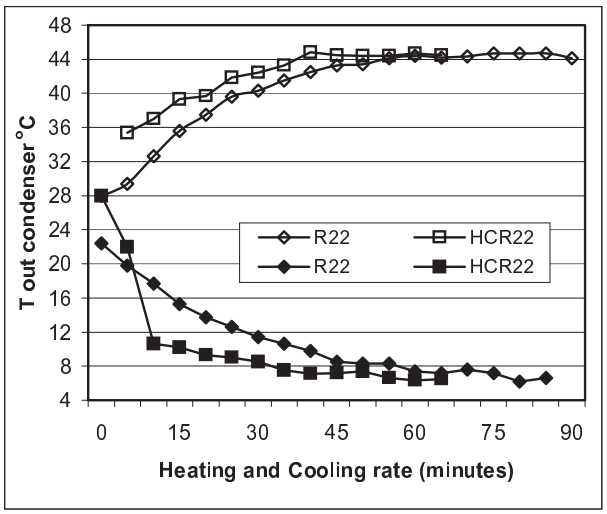


Figure 3: Cooling rate and heating rate of refrigerant HCR22 and R22

Performance of hybrid refrigeration machine : COP, PF and TP at water speed rate in evaporator and condenser at 0.067 kg/s and 0.088 kg/s, with R22 refrigerant and HCR22 refrigerant.

3.2.3 Performance of Hybrid refrigeration machine (COP, PF, TP)

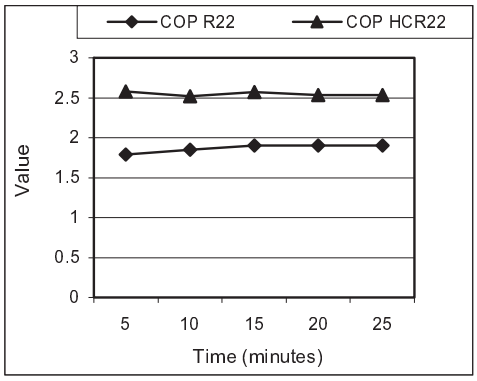


Figure 4: COP hybrid refrigeration machine with HCR22 and R22 refrigerant

The performance of hybrid refrigeration machine is COP, PF and TP at water speed rate in evaporator and condenser at 0.067 kg/s and 0.088 kg/s, with R22 refrigerant and HCR22 refrigerant (figure 4).

From the figures, we knows that COP, PF, ITP with HCR22 at hybrid refrigeration machine higher than R22. COP, PF and TP is 2.548, 3.203 and 5.751 for HCR22. COP, PF and TP is 1.834, 2.62 and 4.454 for R22. HCR22 can absorb energy bigger than R22 at the same pipe volume refrigerant.

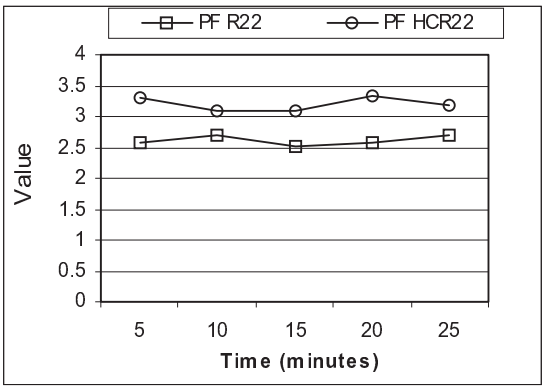


Figure 5: PF hybrid refrigeration machine with HCR22 And R22 refrigerant

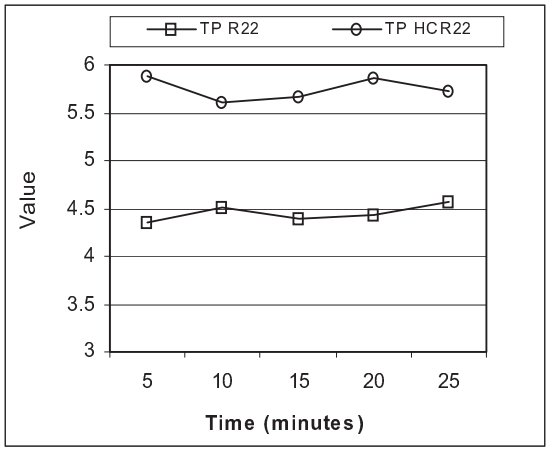


Figure 6: TP hybrid refrigeration machine with HCR22 and R22 refrigerant

3.2.4 Cooling Capacity, Heating Capacity and Power of Compressor

Cooling capacity with HCR 22 higher than cooling capacity with R22, because HCR22 can absorb heat higher than R22, HCR22 have latent heat higher than R22. For the same cooling capacity HCR22 need refrigerant mass lower than R22 (about 50% mass for HCR22 compared to R22). Figure 7 shows cooling capacity between HCR22 and R22 is 1.943 kW and 1 834 kW.

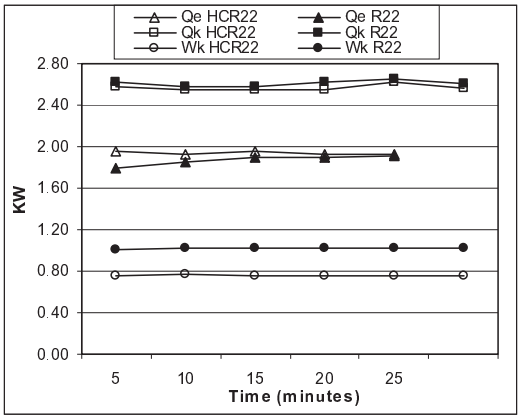


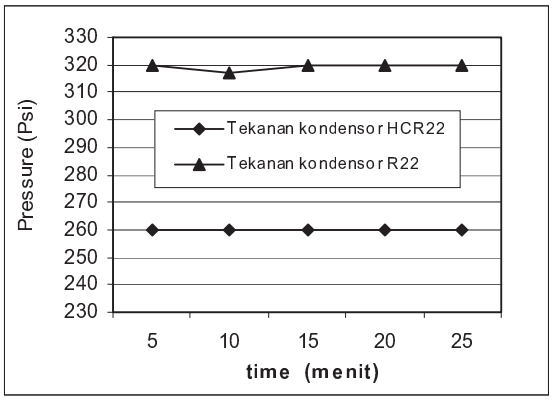
Figure 7: Cooling capacity, heating capacity and power of compressor with HCR22 and R22

Table 1 shows the experimental data form this research, this table summary data from the research.

Table 1: Experimental data research with HCR22 and R22

Heating capacity with HCR22 is lower than heating capacity R22. Because pressure at condenser with R22 higher than HCR22 (figure 8). At higher pressure condenser, the temperature higher too, so heating energy for water at condenser bigger at higher temperature. Figure 7 shows that heating capacity that comparison HCR22 and R22 with heating effect between HCR22 and R22 whereas heating capacity for HSR22 and R22 is 2.567 kW compared to 2.611 kW.

The mean pressure of compressor with HCR22 refrigerant is 260 Psig and the mean pressure of compressor with R22 is 319.4 Psig. Figure 7 shows that the comparison between power of compressor with HCR22 (0.763 kW) to R22 (1.019 kW). The power of compressor with HCR22 more efficient compared to R22 about 25%.



. Figure 8: Pressure at condenser with HCR22 refrigerant and R22 refrigerant

4. CONCLUSION

At this research, from result of design and discussion done to experimental data, can conclude that:

1. Design output from the experimental apparatus is : the length of evaporator pipe is 20.69 *m* with surface area 0.6175 m^2 and heat transfer coefficient 172.7469 $W/(m^2.{}^0C)$. The length of condenser pipe is 21.74 *m* with surface area 0.6489 m^2 and heat transfer coefficient 236.469 $W/(m^2.{}^0C)$. The length of capillary pipe is 1.65 m with 1,7 mm diameter.
2. The use mass of hydrocarbon refrigerant HCR22 more efficient 57.78 % compared to R22 refrigerant, because latent heat of HCR22 higher than R22.
3. Cooling rate and heating rate with HCR22 faster than 33.33 % compared to R22. Performance of HCR22, the COP increase 38.93%, PF increase 22.25% and TP increase 29.12% compared to R22.
4. At the use of hydrocarbon refrigerant HCR22, cooling rate increase 5.94%, while heating rate decrease 1.69% because the pressure of condenser decrease 18.6%. The power of compressor with hydrocarbon refrigerant HCR22 more efficient 25.12 % compared to R22.

Description	Refrigerant	Value	Unit	Result	Efficiency%
Refrigerant Mass	HCR22	380	gram		57.78
	R22	900			
Cooling Rate	HCR22	40	minutes	faster	33.33
	R22	60			
Heating Rate	HCR22	40	minutes	faster	33.33
	R22	60			
COP	HCR22	2.548	unit	Increase	38.93
	R22	1.834			
PF	HCR22	3.203	unit	Increase	22.25
	R22	2.62			
TP	HCR22	5.751	unit	Increase	29.12
	R22	4.454			
Cooling Capacity	HCR22	1.943	kWatt	Increase	5.94
	R22	1.834			
Heating Capacity	HCR22	2.567	kWatt	decrease	-1.69
	R22	2.611			
Condenser Pressure	HCR22	260	Psig	decrease	-18.60
	R22	319.4			
Compressor Power	HCR22	0.763	kWatt	decrease	-25.12
	R22	1.019			

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