Simulation of Mixing Synthetic with hydrocarbons Refrigerant to Reduce the Value of Global Warming Potential with Refprop Software

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Abstract The problem of global warming or called GWP (Global Warming Potential) that occurs in the earth's atmosphere, one of which comes from synthetic refrigerants used in household air-conditioning refrigeration machines. R410A is a refrigerant that still contains GWP: 1942. Hydrocarbon refrigerant is a refrigerant that does not contain ODP (Ozone Depleting Potential) and a very small GWP. By using ref prop software, the mixing process can be simulated to obtain refrigerants that have characteristics similar to R410A. Mixing using R32 / R290 ingredients varied with percentage compositions ranging from 50/50, 40/60, 30/70, 20/80, and 10/90. From the simulation results, a mixture approaching R410A with 10/90 composition with COP: 3.85 for R410A and 5.76 for 10/90 mixture was obtained. Compression ratio: R410A: 2.8 and for mixed refrigerants 10/90: 1.8. The refrigerant effect of mixed refrigerants is 10/90: 264.13, R410A: 161.68. By using this refrigerant mixture can reduce the GWP and improve the performance of the Air Conditioning cooling system so that it has a reduced GWP value that can be obtained significantly and has a large enough potential to replace the R410A.

1. Introduction
Synthetic refrigerants generally contain Chloroand Fluoro which can potentially damage the atmospheric environment or commonly called ODP (Ozone Depleting Potential) and GWP (Global Warming Potential) [1]. R410A refrigerant is a type of mixed (zeotropic) synthetic refrigerant consisting of R32/R125 with the composition (50% / 50%). GWP R410A value of 2088, boiling point: -51.44 °C and critical point: 71.34 °C. In support of regulations initiated by a number of countries with environmental concerns named country article 5, they have agreed to an HCFC removal program and a reduction in GWP contained in refrigerants [1]. Hydrocarbon refrigerant is a type of refrigerant that is friendly to the environment because it does not contain ODP and GWP: <4, but this refrigerant has flammable properties. R290 (propane) refrigerant is a natural refrigerant this is a single refrigerant and has a boiling point of -44.47 °C, a critical temperature of 96.74. R32 is a single refrigerant that has properties similar to R410A, Non-ODP, and Low GWP so that both refrigerants have the potential to be mixed in order to get results that are close to the characteristics of R410A. In conducting experiments and formulating mixtures using Refprop software by analyzing the sides of saturated pressure, temperature, enthalpy, the entropy of refrigerant density[2].
2. Literature Review

The characteristics of refrigerant can be seen from the physical and thermodynamic properties inherent in each refrigerant [1].

| Characteristics                  | $R_{410A}$ | $R_{32}$ | $R_{290}$ (Propane) |
|----------------------------------|------------|----------|---------------------|
| GWP (Global warming potential)   | 2088       | 675      | 3                   |
| ODP (Ozone Depleting Potential) | 0          | 0        | 0                   |
| Normal Boiling Point (°C)       | -51,44     | -51,65   | -42,11              |
| Critical Temp. (°C)             | 71,34      | 78,11    | 96,74               |
| Flammability limit in air (1atm) LFL/UFL | 0      | A2L      | 2-10%               |
| Critical Pressure (Psia)        | 714,5      | 720      | 624,75              |

The methodology used to obtain the results of $R_{32}$ refrigerant mixture with $R_{290}$ by formulating the variable mass of the mixture into refprop software. Mixing simulation is done starting from the mixture with the lowest and highest percentage by taking into account the pressure line graph and saturated steam temperature. By using a graph display of pressure and temperature obtained through the simulation results are then analyzed their performance through calculations with the refprop software. $R_{32}/R_{290}$ refrigerant mixture variations consist of 5 (five) variations; 50/50, 40/60, 30/70, 20/80 and 10/90. Each composition was analyzed and compared with $R_{410A}$ performance. The calculated performance is cooling effect, Compression Work, Coefficient of performance (COP), Compression ratio, Heat discharged through the condenser [4].

Selecting refrigerants as research material with a simulation method with software. Before carrying out the process of mixing refrigerant with refprop software, first look for the characteristics of the refrigerant that has potential and has the characteristics and characteristics close to the $R_{410A}$ refrigerant. Refrigerant to be used as a mixture is $R_{32}$ with $R_{290}$ by varying the composition of the refrigerant mass. From the results of the simulation formulation with software, the results can be seen in Figure 1. below[7]:

![Figure 1. Characteristics Pressure versus Temperature refrigerant](image-url)

The results of the refrigerant mixing are displayed in the form of a graph of pressure versus temperature for each refrigerant mass variable with details can be seen in the picture. Comparison Pressure with temperature can look at figure 2. is below:
Figure 2. Ratio of pressure to the temperature of the refrigerant in the mixture 50/50

The results of the simulation of the ratio of pressure and temperature in the mixture 40/60 there is a little difference with R410A. With details can be seen in figure 3. below:

Figure 3. Ratio of pressure to the temperature of the refrigerant in the mixture 40/60

The results of the simulation of the ratio of pressure and temperature in the mixture 30/70 there is very little difference with R410A only high-pressure little gap. With details can be seen in Figure 4. below:

Figure 4. Ratio of pressure to the temperature of the refrigerant in the mixture 30/70

The results of the simulation of the ratio of pressure and temperature in the mixture 20/80 there is a very closed with R410A only high pressure the bigger gap. With details can be seen in Figure 5. below:
Figure 5. Ratio of pressure to the temperature of the refrigerant in the mixture 20/80

The results of the simulation of the ratio of pressure and temperature in the mixture 10/90 differences are starting from the temperature of 15-40 °C compared with R410A. With details can be seen in Figure 6.Below:

![Figure 5](image-url)

Figure 6. Ratio of pressure to the temperature of the refrigerant in the mixture 10/90

Comparison of simulation results of the refrigeration effect between R410A refrigerant and mixed refrigerant. mixed a refrigerant the refrigeration effect is obtained very large because by using R290 it has a smaller density and a large latent heat value. can be seen in figure 7. below:

![Figure 6](image-url)

Figure 7. Graph comparison refrigeration effect

Comparison of simulation results of the refrigeration effect between R410A refrigerant and mixed refrigerant. a mixed refrigerant the is obtained Compression work very big depend on R410A,
especially for mix 30/70 getting low work compression. because by using \textit{R290} it has a smaller density and a large latent heat value. can be seen in figure 8. below:

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig8.png}
\caption{Graph comparison work of compression}
\end{figure}

Comparison of simulation results of the COP between \textit{R410A} refrigerant and mixed refrigerant. a mixed refrigerant the is obtained Compression work very big depend on \textit{R410A}, especially for mix 10/90 getting high COP. because by using \textit{R290} it has a smaller density and a large latent heat value. can be seen in figure 9. below:

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig9.png}
\caption{Graph comparison COP (Coefficient of performance)}
\end{figure}

From the results of calculations using refprop software for \textit{R32/R290} refrigerant mixture, the performance results in table 2. below are obtained:

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
\textbf{Description} & \textit{R410A} & \textit{Refrigerant Mix Composition} & & & \\
& (50/50) & (40/60) & (30/70) & (20/80) & (10/90) \\
\hline
Refrigeration Effect(kJ/kg) & 161.68 & 268.31 & 216.59 & 230.66 & 245.82 & 264.13 \text{ T\textsubscript{evap} : 15°C} \\
Work Compression (kJ/kg) & 41.99 & 67.69 & 58.69 & 47.98 & 60.48 & 45.88 \text{ T\textsubscript{Cond} : 40 °C} \\
Compression Ratio & 2.00 & 1.80 & 2.20 & 1.90 & 1.90 & 1.80 \\
Heat of Condenser(kJ/kg) & 203.67 & 336 & 275.28 & 278.64 & 306.3 & 310.01 \\
COP & 3.85 & 3.96 & 3.69 & 4.81 & 4.06 & 5.76 \\
\hline
\end{tabular}
\caption{Result of calculation Performance with software Simulation}
\end{table}

3. Conclusions
Optimal refrigeration effects are found in refrigerants with a mixture \textit{R32/R290}composition of 10/90 with a refrigeration effect: 264.13 kJ /kg its very big if we compare with \textit{R410A} because hydrocarbons
refrigerant has latent heat bigger than R410A caused extend for refrigeration effect area.

Using refrigerant mix can get higher compression work is obtained in refrigerants with a mixture for the all composition if we compare with R410A because influence for R32 substance of high pressure.

The most optimal COP of each composition is in the highest mixture 10/90 is 5.76 for all mixtures and R410A with a value: 3.85 because influence from refrigeration effect and latent heat for R290 is very high. And also R32 has normal boiling point is -51.76°C.

The heating value in the condensation process occurs in the most efficient condenser is a refrigerant with a composition of 40/60 with a value of 275.28 kJ/kg

Performance Results R32/R290 Hydrocarbon refrigerant mixture.

As a suggestion to continue the performance test direct on the Air conditioning unit

References

[1] UNEP, 2007. UNEP/Ozl. Pro. 19/7, Report of the 19th Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer. Nairobi, Kenya.

[2] BOC-CARE refrigerants, 2007. Hydrocarbons as refrigerants in small heat pump and Refrigeration systems e a review. Int. J. Refrigeration 31 (4), 552e563. Available from: http://www. care-refrigerants.co.uk/ (accessed 2012.02.19.) citing from Palm, B., 2008.

[3] Velders, G.J.M., Fahey, D.W., Daniel, J.S., McGarland, M., Andersen, S.O., 2009. The large contribution of projected HFC emissions to future climate forcing. PNAS 106 (27), 10949e10954.

[4] Zhou, G.B., Zhang, Y.F., 2010. Performance of a split-type air conditioner matched with coiled adiabatic capillary tubes using HCFC22 and HC290. Appl. Energ. 87 (5), 1522e1528

[5] Teng, T.P., Mo, H.E., Lin, H., Tseng, Y.H., Liu, R.H., Long, Y.F., 2012. Retrofit assessment of window air conditioner. Appl. Therm. Eng. 32, 100e107.

[6] Padalkar, A.S., Mali, K.V., Rajadhyaksha, D.D., Wadia, B.J., Devotta, S., 2010. Performance assessment of air conditioners with HC290. 9th IIR Gustav Lorentzen Conference, Sydney, Australia.

[7] Hoehne, M.R., Hrnjak, P.S., 2004. Charge Minimization in Systems and Components Using Hydrocarbons as a Refrigerant. Air Conditioning and Refrigeration Center. College of Engineering. University of Illinois, Urbana, USA

[8] Widodo, Fatkhr R, Ade Irvan T International 15-16th October 2019 Analysis of Savings on Electricity Consumption in Air Conditioning Room by Using Refrigerant R-1270 (Propylene) Instead of R-32 capacity of 13,000 Btuh Journal of Physics: Conference Series 1477 (2020) 052035 doi:10.1088/1742-6596/1477/5/052035.