Influence of Intermediate Heat Exchanger on HFO1234yf/HFC134a Mixed Working Vehicle Air Conditioner

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**Abstract:** This paper mainly analyzes the influence of intermediate heat exchangers on the performance of mixed refrigerant automotive air conditioners. Firstly, the theoretical analysis of the working condition of the automobile air conditioner after adding the intermediate heat exchanger is carried out, and the experimental platform of the automobile air conditioner is built according to the theoretical result; then the actual test is carried out in the test bench of the automobile air conditioner, and finally compared with the theoretical analysis. The experiment shows that the cooling capacity of HFO1234yf/HFC134a mixed working fluid is increased after adding the intermediate heat exchanger, which is slightly higher than that of R134a without intermediate heat exchanger: the cop aspect is less, and the COP is lower under high temperature. Compared with the mixed working medium without intermediate heat exchanger, the air conditioning refrigeration capacity and cop are increased by about 4% and 3%.

**Introduction**

In today's society, environmental protection and energy conservation has become the most important criterion for measuring the performance of vehicle air conditioners. As the blood in the vehicle air conditioner, the refrigerant is developing in the direction of safety, environmental protection, high efficiency, energy saving, recycling, and easy manufacturing. HFO1234yf/HFC134a mixed working fluid is not easy to burn at a certain ratio, and the complementary advantages of the two refrigerants are feasible directions for the development of automotive air conditioner refrigerants in the future.

According to the principle of ensuring that the mixed working medium is non-flammable, taking into account the complementary advantages of HFO1234yf and HFC134a and meeting the F-gas regulations (GWP less than 150), this paper proposes a mixed working medium with HFO1234yf/HFC134a mass ratio of 89/11. The working medium is non-toxic and non-combustible, ODP=0, GWP=144.

Adding an intermediate heat exchange device to the theoretical refrigeration cycle, that is, the Carnot cycle, causes the working fluid to be super cooled, the steam is overheated, and the refrigeration efficiency is improved. Initially, intermediate heat exchangers were commonly used in carbon dioxide transcritical cycle systems. Klein S A et al.\textsuperscript{[1]} and Mastrullo R et al.\textsuperscript{[2]} found through experiments that the intermediate heat exchanger is not only beneficial to the carbon dioxide transcritical cycle refrigeration system, but also has good effects in other refrigeration cycles. However, in practical applications, the added heat exchanger will increase the system load so that its positive and negative effects on the whole system cancel each other out, and even the negative impact on the whole system is greater than the positive impact\textsuperscript{[3,4]}. Therefore, there has been great resistance in the application of intermediate heat exchangers for automotive air conditioners.

For the new hybrid refrigerant air conditioner, it is quite necessary to study the effect of the regenerator on the mixed working medium vehicle air conditioner.
Theoretical analysis of heat exchangers

The principle of the intermediate heat exchanger is to exchange the low temperature and low pressure gaseous refrigerant from the outlet of the evaporator and the high temperature and high pressure liquid refrigerant at the outlet of the condenser into the heat exchanger for heat exchange. In the refrigeration cycle, the liquid is too cold, the steam is overheated, and the degree of subcooling of the system increases. In this way, the compressor suction gas can be overheated, the liquid refrigerant can be prevented from entering the compressor, and the heat exchange efficiency of the evaporator can be improved. The schematic diagram of the heat exchanger is refer with Figure 1, and the pressure diagram is refer with Figure 2.

![Figure 1 Intermediate heat exchanger schematic](image1)
![Figure 2 lgP-h diagram of heat regeneration system in theory](image2)

In the figure 2, 1’-2’ indicates a process in which a low-temperature low-pressure refrigerant gas is compressed into a high-temperature high-pressure gas. 2’-3 represents the process of entering the condenser from the high temperature and high pressure gas coming out of the compressor. 3-3’ is a process in which the condensed refrigerant liquid is further cooled in the intermediate heat exchanger. 3’-4’ indicates that the high-pressure refrigerant liquid is throttled into a low-temperature low-pressure two-phase state. 4’-1 is a process in which a low-temperature low-pressure two-phase state refrigerant enters the evaporator. 1-1’ is a process in which the superheated gas enters the intermediate heat exchanger and exchanges heat with the high temperature and high pressure liquid from the condenser. The cycle without intermediate heat exchanger can be represented by 1-2-3-4 in the figure, and the cycle with intermediate heat exchanger can be represented by 1’-2’-3’-4’ in the figure. The evaporation process of the evaporator became 4’-1 and the evaporation process without the intermediate heat exchanger increased by 4’-4.

After theoretically adding the intermediate heat exchanger, the cooling capacity Q and system COP of the system will increase.

Experimental preparation

In this experiment, the enthalpy difference method was used to measure the influence of the intermediate heat exchanger on the entire air conditioning system.
The experimental results were made more accurate by measuring the latent heat of the condensate in the evaporator in the experimental system\footnote{5}. The schematic diagram of the experimental bench is shown in Figure 1. In this experiment, five working conditions are set according to the actual situation, as shown in Table 1:

<table>
<thead>
<tr>
<th>Working condition number</th>
<th>Rotating speed (rev/min)</th>
<th>Dry-bulb temperature (°C)</th>
<th>Relative humidity (%)</th>
<th>Air volume (kg/min)</th>
<th>Dry-bulb temperature (°C)</th>
<th>Air volume (kg/min)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>2000</td>
<td>27</td>
<td>45</td>
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<td>30</td>
<td>28</td>
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<td>3000</td>
<td>27</td>
<td>45</td>
<td>5.5</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>4000</td>
<td>27</td>
<td>45</td>
<td>8.2</td>
<td>30</td>
<td>31.8</td>
</tr>
<tr>
<td>4</td>
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<td>25</td>
<td>45</td>
<td>5.5</td>
<td>38</td>
<td>31.8</td>
</tr>
<tr>
<td>5</td>
<td>3000</td>
<td>38</td>
<td>45</td>
<td>8.2</td>
<td>43</td>
<td>31.8</td>
</tr>
</tbody>
</table>

**Effect of heat exchanger on system performance**

Experiments were carried out on the performance of HFO1234yf/HFC134a with intermediate heat exchangers and HFO1234yf/HFC134a and HFC134a without intermediate heat exchangers in automotive air conditioning refrigeration mode.

**Figure 3** The cooling capacity of HFO1234yf/HFC134a with IHX in comparison with HFO1234yf/HFC134a and HFC134a without IHX under cooling mode.

**Figure 4** The COP of HFO1234yf/HFC134a with IHX in comparison with HFO1234yf/HFC134a and HFC134a without IHX under cooling mode.

**Effect of intermediate heat exchanger on cooling capacity.** The comparison of the cooling capacity of HFO1234yf/HFC134a with intermediate heat exchanger and HFO1234yf/HFC134a and HFC134a without intermediate heat exchanger in automobile air conditioner is shown in Figure 3. The cooling capacity of HFO1234yf/H-FC134a introduced into the intermediate heat exchanger is increased by 2%-4%, which is slightly higher than HFC134a. After the introduction of the intermediate heat exchanger, Mixed refrigerant has sufficient subcooling capacity for the refrigerant before entering the expansion valve due to its own thermophysical properties, and increases the latent heat of evaporation of the refrigerant in the evaporator to compensate for the mass flow.
Effect of intermediate heat exchanger on COP. The COP comparison of the intermediate working heat exchanger with the mixed working medium and the HFC134a without intermediate heat exchanger in the automobile air conditioner is shown in Figure 1. Under low temperature conditions, the COP of the system increased by 3% and 1% respectively after the mixed working fluid was introduced into the intermediate heat exchanger. Under high temperature conditions, the COP of HFO1234yf/HFC134a introduced into the intermediate heat exchanger system is reduced by 2%. This is because the power of HFO1234yf/HFC134a increases greatly after the introduction of the intermediate heat exchanger under high temperature conditions.

Figure 5 The compressor discharge temperature of HFO1234yf/HFC134a with IHX in comparison with HFO1234yf/HFC134a and HFC134a without IHX under cooling mode

Effect of intermediate heat exchanger on exhaust gas temperature. The effect of the intermediate heat exchanger on the system exhaust temperature is shown in Figure 5. After HFO1234yf/HFC134a was introduced into the intermediate heat exchanger, The exhaust gas temperature increased by an average of 12°C, which is about 2°C higher than HFC134a. The refrigerant at the outlet of the evaporator is further superheated by the intermediate heat exchanger to cause the temperature of the exhaust gas to rise.

Conclusions

The experimental results show that HFO1234yf/HFC134a increases the cooling capacity by 2%-4% after introduction into the intermediate heat exchanger. Under low temperature conditions, the COP increased by 1%-3% after HFO1234yf/HFC134a was introduced into the intermediate heat exchanger. Under high temperature conditions, the COP decreased by 2% after HFO1234yf/HFC134a was introduced into the intermediate heat exchanger. The reason for this difference is that the overall efficiency of the compressor is ignored in the simulation. After HFO1234yf/HFC134a was introduced into the intermediate heat exchanger, the simulated compressor exhaust temperature was improved. It was found that the exhaust gas temperature of HFO1234yf/HFC134a was increased by 12°C after the introduction of the intermediate heat exchanger.

In summary, the introduction of the intermediate heat exchanger has a certain improvement on the COP of the system under low temperature conditions, and the high ambient temperature will adversely affect the COP of the system.

Acknowledgements

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References


