An Investigation on the Performance of Refrigerator Compressor When Using HFC152a/ HCFC22 Mixture to Substitute CFC12

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AN INVESTIGATION ON THE PERFORMANCE OF REFRIGERATOR COMPRESSOR WHEN USING HFC152A/HCFC22 MIXTURE TO SUBSTITUTE CFC12

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ABSTRACT

When CFC12 is substituted by use of HFC152a/HCFC22 mixture, the performances of refrigerator compressor including consumed power, refrigerating capacity, volume efficiency, will be variable from using CFC12. So, the compressor should be redesigned or improved.

In this paper, firstly, the thermoproperties of HFC152a/HCFC22 were precisely calculated by using PR equation of state combined with mixture rule and thermodynamic relations. The data base of thermoproperties was built to be called when predicting performance of compressor.

Secondly, the refrigerator compressor was predicted theoretically and verified experimentally. The mathematical model was built according to energy equation, mass flow equation, mass equilibrium equation and heat transfer equation. The software package of compressor performance simulation was provided depending upon finite unit method, and some characteristics of compressor, those are valve behaviour, indicated power and refrigerating capacity, were predicted by use of this package. Based on the model, the satisfied results were gotten from the verified experiment.

1. NOMENCLATURE

Q ------- Heat, J;
W ------- Work, J;
U ------- Internal energy of gas, J;
t ------- Time, s;
m ------- Mass, kg;
h ------- Specific enthalpy, J/kg;
p ------- Pressure, Pa;
T ------- Temperature, K;
v ------- Specific volume, m^3/kg;
R ------- Gas constant, Pa. m^3/ (kg. K);
Sr ------ Residual entropy, J/ (kg. K);
Re ------ Reynel's number;
Pr ------ Prandtl number;
Nu ------ Nusselt number;
β ------ Factor of gas push-force;
av ------ Areas of valve gap port, m^2;

k ------- Adiabatical index of gas;
Mv ------ Mach number of the valve gap;
------ Crankangle.

SUBSCRIPT

s ------- Suction;
sp ------ Suction pipe;
m ------- Mixture;
d ------- Discharge;
dp ------ Discharge pipe;
w ------- Wall of cylider.

SUPERSCRIPT

* ------ Ideal gas.

2. INTRODUCTION

HFC152a/HCFC22 is a prospective alternate in searching the candidate for the replacement of CFC12 in refrigerator. It was reported [1] that the HFC152a/HCFC22 mixture has very small values of ODP and GWP and the consumed power of refrigerator, with the mixture, was less 6.9% than that with CFC12. Because the thermodynamic properties of HFC152a/HCFC22 mixture are different from that of CFC12, the performances and efficiency of the compressor, suited for using the CFC12 refrigerant, will be changed when CFC12 is replaced by the HFC152a/FCFC22 mixture. So, it is necessary for the components of the compressor to be adjusted or redesigned to suit with the thermodynamic properties of HFC152a/FCFC22. In this paper, the performances of refrigerator compressor, on the base of the mathematical model of compressor, were predicted by computer simulating when the HFC152a/HCFC22 mixture being used. Also, some measures to develop the performances of compressor were put forward.

3. MATHEMATICAL MODEL OF THE COMPRESSOR

Shown as Figure 1, the control volumes, used for building mathematical model, include the suction chamber, the discharge chamber and the cylider. Some hypotheses are taken as follows:

1). At any moment, the parameters of state of the refrigerant at any point within the control volume are the same.
2). Gas leakage between the piston and the cylider wall can be regarded as negligible.
3). Kinetic energy and potential energy for the refrigerant are not varied.
4). The changing of thermodynamic parameters of the refrigerant within the valves are left out of consideration.

(A). Applying energy equation to the control volumes:

1). Cylider

Suction process

$$\frac{dm}{dt} \cdot h_s + \frac{dQ}{dt} - \frac{dW}{dt} = \frac{dU}{dt} \tag{1}$$

Discharge process

$$-\frac{dm}{dt} \cdot h - \frac{dQ}{dt} + \frac{dW}{dt} = \frac{dU}{dt} \tag{2}$$

2). Suction chamber

$$-\frac{dm_s}{dt} \cdot h_s + \frac{dm_{sp}}{dt} \cdot h_{sp} + \frac{dQ_s}{dt} = \frac{dU_s}{dt} \tag{3}$$

3). Discharge chamber

$$\frac{dm_d}{dt} \cdot h - \frac{dm_{dp}}{dt} \cdot h_d - \frac{dQ_d}{dt} = \frac{dU_d}{dt} \tag{4}$$

Here, the enthalpy value of the refrigerant can be found by using the gas-mixing rule, residual enthalpy formula and PR equation of state. i.e.

$$ar_m = \int_{\infty}^{v_m} (p_m - R_m T / v_m) \cdot dv_m + R_m \cdot T \cdot \ln \frac{v_m}{v_m^*} \tag{5}$$

$$sr_m = -\left(\frac{\partial ar_m}{\partial T}\right)_{v_m} \tag{6}$$

$$h_m = -(ar_m + T \cdot sr_m + R_m \cdot T \cdot (1 - Z)) + h_m^* \tag{7}$$

(B). Mass equilibrium equation:

$$\frac{dm}{dt} = \frac{dm_i}{dt} - \frac{dm_o}{dt} \tag{8}$$

(C). Heat transfer equation:

1). Heat transfer capacity between the refrigerant and the cylider wall

$$\frac{dQ}{dt} = \alpha \cdot [A_p \cdot (T_{w1} - T) + A_{cy} \cdot (T_{w2} - T)] \tag{9}$$

Where, Api----- Areas of upper part of piston, m^2;
Acy----- Transient mirror areas of cylider, m^2;
α ----- Coefficient of convective heat transfer, that got by the following formula [2].

$$Nu(\theta) = 0.053 \cdot Re(\theta)^{0.8} \cdot Pr(\theta)^{0.6} \tag{10}$$

2). Heat transfer capacity of suction chamber or discgarge chamber

$$\frac{dQ_{sd}}{dt} = \alpha_{sd} \cdot A_{sd} \cdot (T_{sd} - T_w) \tag{11}$$

Where, Asd ------ Heat transfer area of suction chamber, m^2;
Tsd ------ Temperature of the refrigerant in suction chamber or discharge chamber, K;
Tw ------ Surface temperature of suction chamber wall or discharge chamber wall, K;

$$\alpha_{sd} = 0.063 \cdot Re^{0.75} \cdot Pr^{0.4} \tag{12}$$

(D). Moving equation of the reed sheet:

Because the valve-sheet of the compressor in refrigerator are usually the shape of reed, the moving equation of reed sheet is given by the use of variational principle [3].

The above simultaneous equations are solved by computer, and the simulated characteristic parameters of the refrigerator compressor can be obtained.

4. PREDICATING THE PERFORMANCE OF COMPRESSOR AFTER CFC12 BEING REPLACED BY HFC152A/HCFC22 MIXTURE

After HFC152a/HCFC22 mixture was substituted for CFC12, the woking condition for the components of compressor is changed as the thermodynamic properties are different between CFC12 and HFC152a/HCFC22. This changing has an even great effect on the valve. In Figure 2, the movement of reed sheet, acted jointely by the spring-force (Fsp) and the refrigerant gas-force (Fg), is shown. Here, Fsp is determined by the dimension of valve, and Fg is relative to the thermodynamical preperties of refrigerant. That is:

$$F_g = \beta \cdot a_v \cdot p \cdot \frac{\pi^2 \cdot k \cdot M_v^2}{8} \tag{13}$$

The change of Fg, caused by the different properties of refrigerant, will lead to the variation of moving characteristics of the valve. So, it is necessary to adjust the dimension of components in compressor when CFC12 is replaced.

In this paper, a QD67A type compressor was took as the objective for researching. The performances of the compressor, used CFC12 and HFC152a/HCFC22 respectively, were predicted by computor simulating technology

With the dimension of the compressor did not make any changing, Figure 3. shows the consumed power by the compressor with CFC12 or HFC152a/HCFC22 in one cycle. The calculated results show that the consumed power of compressor, when the HFC152a/HCFC22 mixture being used, is about 3% higher than that when CFC12 being used.

The curve shown in Figure 4 indicates the relationship between the input power of compressor and the length of piston stroke. From this figure, the input power of compressor increases as the length of piston stroke grows, and the more the length of piston stroke increasing, the more the growth rate of the input power of compressor rising. The predicted result shows that the length changing of piston stroke to a compressor should be limited in an appropriate range when CFC12 being replaced.

Figure 5 shows that the lose of suction pressure for copressor rises corresponding to the length of the piston stroke increasing when HFC152a/HCFC22 mixture being uesd.

In Figure 6, the dotted line indicates the displacement of reed sheet with HFC152a/HCFC22 mixture refrigerant when the thick of the reed sheet being adjusted, and the solid line shows that with CFC12 refrigerant when the thick of the reed sheet being not adjusted. It is obvious that the valve sheet has a better movement characteristic after its thick being adjusted.

5. CONCLUSION

With deriving the mathematical model and doing computer simulation, the performance parameters of the compressor in working process can be predicted and a analytical method is provided to adjust the components dimensions of compressor for the replacement of CFC12.

The predicted results shows that when the mixture refrigerant HFC152a/HCFC22 is substituted for CFC12, the same or even a little higher efficiency of compressor than that of original compressor used CFC12 refrigerant may be got only if the dimension of component of the compressor being made some appropriate changing.

6. REFERENCES

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[3]. Zhong Shilian, Ye Shuchun, et al, The differential equations of the mathematical model for compressor valve. Compressor Technology, 1990.

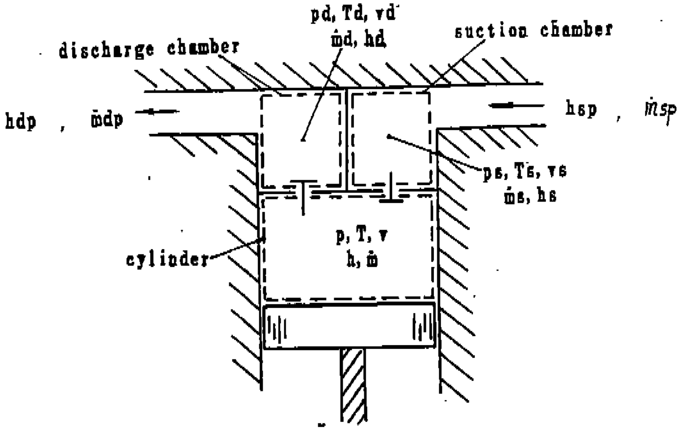

Figure 1. The model graph of compressor

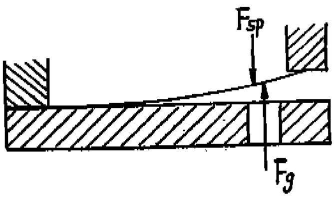

Figure 2. The forces acted on the reed

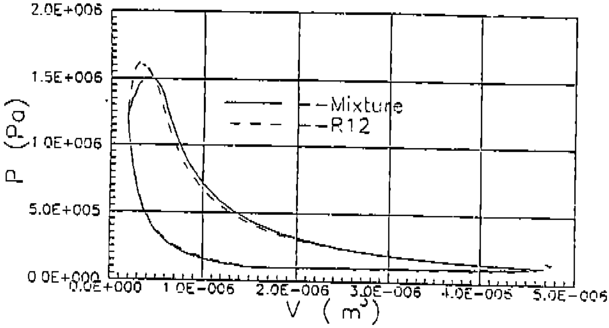

Figure 3. The consumed power by compressor with CFC12 or HFC152a/HCFC22 in a cycle

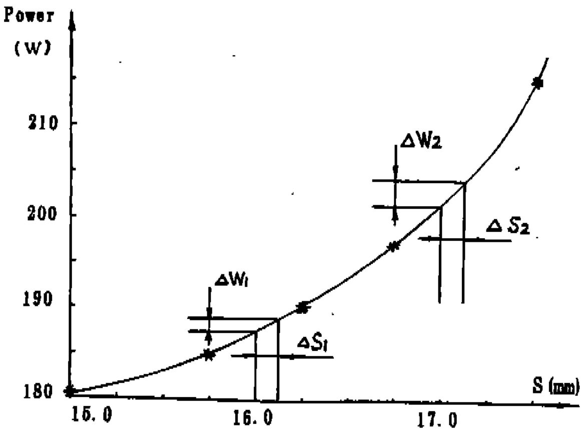

Figure 4. The relationship of the input power and the piston stroke

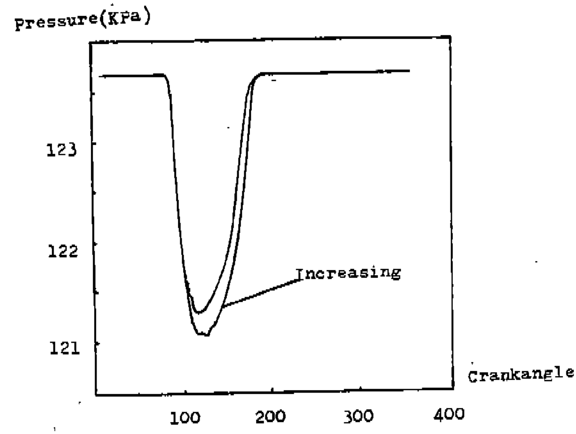

Figure 5. The lose of the suction pressure after the length of piston stroke being changed

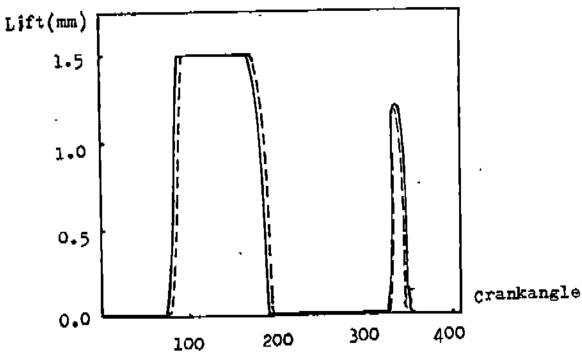

Figure 6. The moving curves of the reed sheet after its thick being changed