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RELIABILITY STUDY OF COMPRESSOR FOR ROOM AIR CONDITIONERS USING HFC BASED REFRIGERANT

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ABSTRACT

Main candidates of alternative refrigerant for HCFC22 used in air conditioning system are HFC based blended refrigerants. Especially R407C and R410A are researched with first priority by many compressor and air conditioner manufacturers. HFC based refrigerants have disadvantage in lubrication because of their molecule composition and we estimated them from tribological point of view. As a result, we have found several possible modification for lubricant and materials to maintain the reliability of compressors used in the HFC based refrigerant system.

INTRODUCTION

HFC based refrigerants have disadvantage in lubrication because they have no chlorine which is one of the compositions in HCFC. Chlorine can avoid metal contact between sliding surfaces in a compressor because it makes extreme pressure. We should pay much attention on this point to maintain the reliability of compressors using R407C or R410A. In this paper, to achieve sufficient reliability for rotary type or scroll type compressors used in room air conditioners, miscibility of oil and refrigerant, sliding materials were estimated and reliability test was carried out for compressors using modified oil and materials.

TECHNOLOGY FOR RELIABILITY OF ALTERNATIVE REFRIGERANT SYSTEM

Fig.1 is the schematic diagram of a refrigeration system and some important reliability issues are shown. Fig.2 is the summary of tribological issues of a compressor.[1),2)]

As shown, it is important to chose oil and sliding materials and keep the stability of oil and refrigerant in a system. Fig.3 is a sectional view of a rotary compressor and Fig.4 is that of a scroll compressor. Both of them have hermetic case filled with high pressure refrigerant gas and oil charged. Each type has each portion of sliding parts and several modifications should be necessary to maintain reliability for HFC refrigerants.

Oil miscibility

Table 1 shows the several kinds of polyol ester with mineral oil as a reference. Miscibility with refrigerants is one of the most important issues for oil. In air conditioning use, the critical soluble temperature should be kept over around -10 deg.(C)and as shown in Fig.5, the combinations of refrigerant and oil shown below can realize it.

Refrigerant/Oil
R407C/E5,E1,E2(Maximum viscosity should be below E5)
R410A/E2(Maximum viscosity should be below E2)

As a result, we have chosen the ester oil of maximum viscosity to keep the oil film thickness sufficiently.

Oil viscosity

Fig.6 shows the absolute viscosity change with pressure and temperature of oil/refrigerant mixtures. [3] The viscosity at 40 and 60 deg.(C) can be read from this figure as shown below.

(1) at saturate vaporizing pressure (MPa.g)

R410A:	40 deg. (C) : 2.416	60 deg. (C) : 3.817
R407C:	: 1.541	:2.426
R22:	: 1.533	:2.522

R22≒R407C<R410A

(2) at saturate solubility of refrigerant (cp)

40 deg. (C) R410A(0.50)<R22(1.7)<R407C(2.5)
60 deg. (C) R22(0.55)<R410A(0.60)<R407C(1.3)

When the temperature of a compressor is between 40 and 60 deg(C), R407C/Oil mixture has higher viscosity than R22/Oil mixture and hydrodynamic lubrication can be realized.

Otherwise, R410A/Oil mixture has approximately the same viscosity of R22/Oil mixture but R410A makes the load of 1.5 times of R22 at sliding parts so some design modification of sliding part portion is necessary to maintain reliability.

Sliding materials

Fig.7 shows the result of Falex test using several combinations of sliding materials. By considering the two types of compressors, rotary type and scroll type, steel, casting iron and aluminum materials were chosen for the test. We also estimated the effect of the acid in oil. We can find out from the results that we should be careful in designing the sliding part with using aluminum materials and system control and process control is required to prevent extremely high temperature and contaminant that cause the deterioration of oil.

RELIABILITY TEST

We carried out system drop-in test with using the unit shown in Fig.8. Of course, this system is the same system used for R22 air conditioners.

In this test we estimated the condition of sliding parts by calculating the oil film thickness from actual oil viscosity. In R407C/POE(VG68) system, of course it can be happened in the air conditioning system using the other refrigerants, the oil film thickness became minimum at the defrosting mode, because liquid refrigerant goes back into a compressor especially in this mode.

Table 2 is the summary of the operating mode and oil film thickness. In rotary type compressors, lubrication is the most severe at pin portion and some design modification (portion or material) is expected to be done.

Table 3 shows the condition of reliability test using scroll compressors with R407C refrigerant. The test carried out in two different conditions to estimate the reliability in inverter controlled operations.

The result was good as shown in Table 4. No particular damage was found in each sliding part and we can realize that basically R407C system has sufficient reliability. But we should estimate more samples in consideration with the other issues like contaminant and so on.

CONCLUSION

We estimated the reliability of HFC based refrigerant system from the tribological point of view and we have found that;

(1)The polyol ester oils chosen for R407C and R410A can realize the critical soluble temperature below -10 deg (C).
(2)The viscosity of oil should be maximum in the range which can meet the miscibility demand to keep the oil film thickness sufficient.
(3)System control and process control should be carefully done to prevent the deterioration of oil because acid in oil makes the damage of sliding parts worse.
(4)System drop-in reliability test was carried out and basically, the reliability can be maintained. But we should do further evaluation in consideration with the other issues like contaminant and so on.

REFERENCE

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3)T.Katoh : "Pressure and absolute viscosity correlations" Japan Sun Oil Co. Technical data, 1995

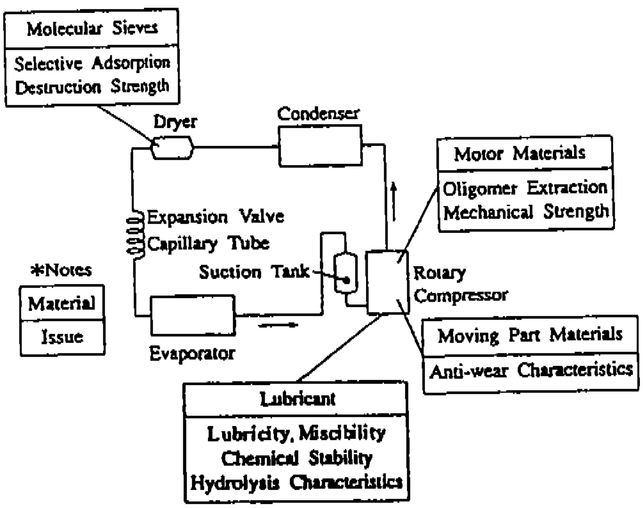

Fig. 1 Schematic Diagram of a Refrigeration System

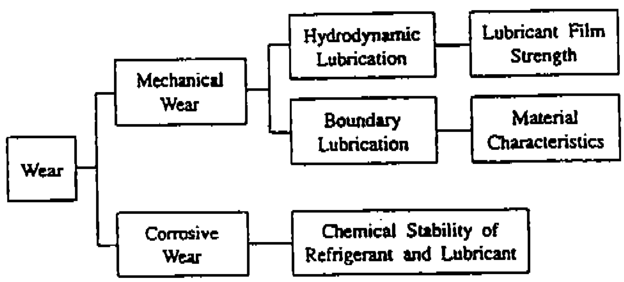

Fig. 2 Tribological Issues of Refrigeration Compressor

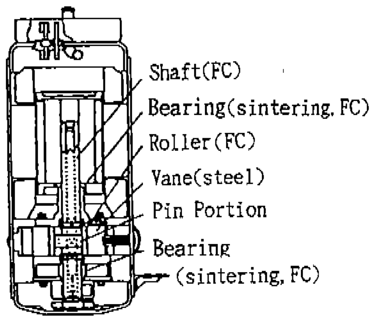

Fig. 3 Rotary Compressor

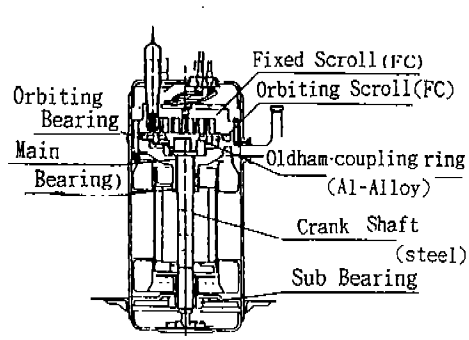

Fig. 4 Scroll Compressor

Table 1 Refrigerating Oil

Oil	Base Oil		Viscosity (mm^2/s) 40℃	100℃	Pour point (℃)	Critical Soluble Temp. (℃) HFC32	HFC125	HFC134a
E1	trimethylolpropane/ i-Cn acid ester		31	5	< −40	15	−45	−43
E2	trimethylolpropane/ i-Cn acid ester		56	8	< −40	> 20	−20	−15
E3	pentaerythritol	i-Cn acid ester	31	5	< −40	> 20	< −80	−36
E4	pentaerythritol	i-Cn acid ester	56	8	< −40	> 20	< −80	−29
E5	pentaerythritol	i-Cn acid ester	68	8	< −40	> 20	< −80	−16
E6	pentaerythritol	i-Cn,n-Cn acid ester	30	5	< −40	−24	< −80	−70
M1	naphthenic mineral oil		56	6	< −40	> 20	> 20	> 20

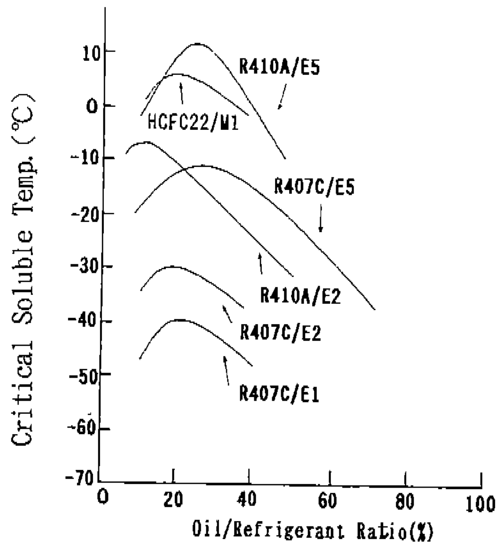

Fig. 5 Oil and Critical Soluble Temp.

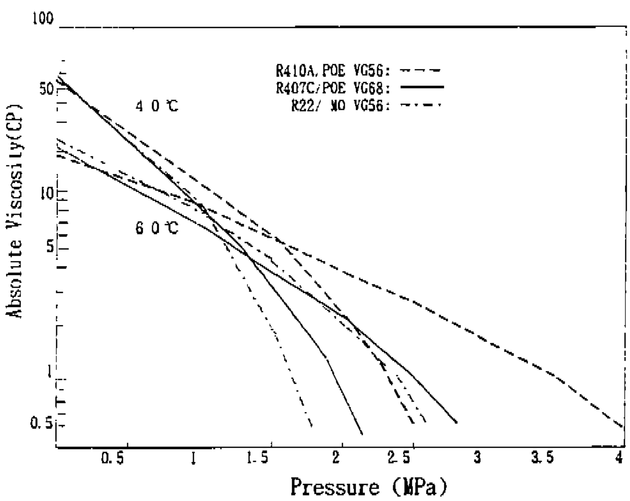

Fig. 6 Pressure and Absolute Viscosity Correlations

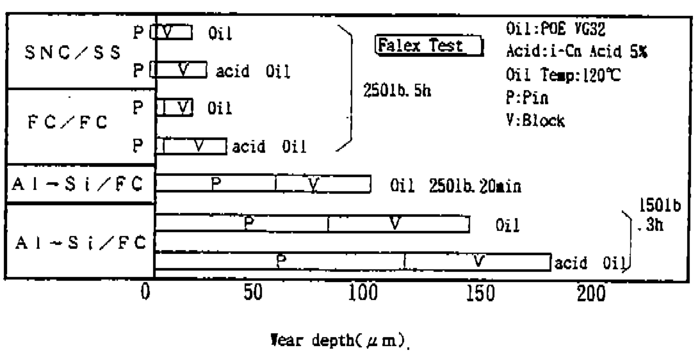

Fig. 7 Sliding Materials and Wear Property

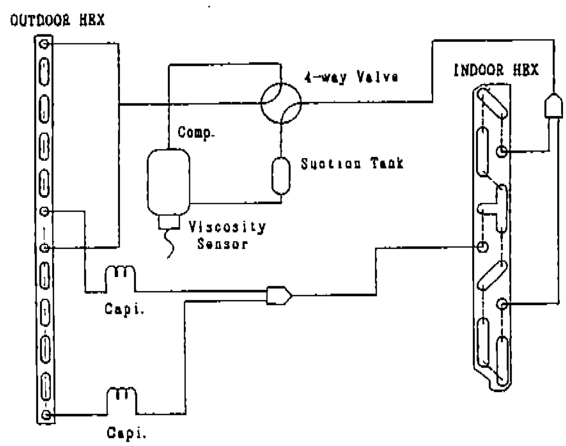

Fig. 8 Schematic Diagram of System Drop-in Test Unit

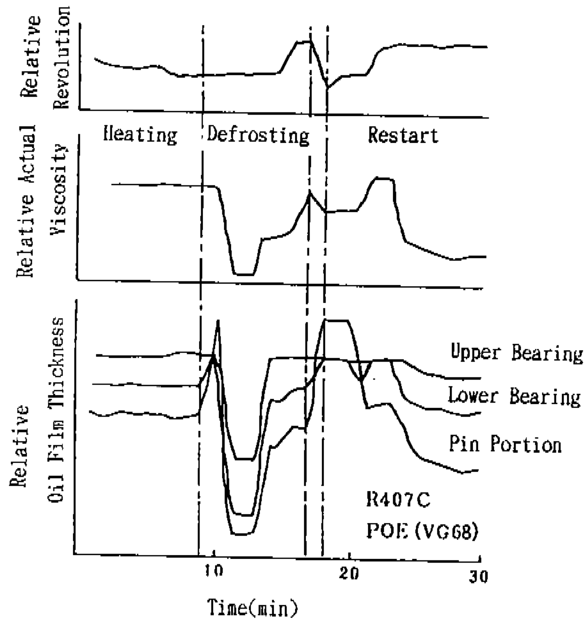

Fig. 9 Change of Oil Film Thickness during Heating, Defrosting and Restarting

Table 2 Operating Mode and Oil Film Thickness (Relative)

Operating mode	R407C/POE			HCFC-22/MO		
	Upper Bearing	Pin Portion	Lower Bearing	Upper Bearing	Pin Portion	Lower Bearing
Starting Cooling Mode (15℃)	5.3	1.9	3.4	5.3	1.9	3.4
Starting Heating Mode (-10℃)	4.7	1.4	2.5	3.9	1.0	1.7
Defrost (2℃)	3	0.7	1.2	—	—	—

Table 3 Condition of Reliability Test

Test condition	High Speed	Heavy Load
Compressor	Scroll	
Fixed Scroll	FC	
Orbiting Scroll	FC	
Refrigerant	R407C	
Refrigerating Oil	POE VG56(E5)	
Suction Pressure (MPa)	0.40	0.59
Discharge Pressure (MPa)	1.57~1.87	2.85~2.94
Revolution(min^{-1})	8250	5700
Time(days)	90	

Table 4 Result of Reliability Test

Compressor		Scroll	
Refrigerant		R407C	
Test condition		High Speed	Heavy Load
Crank Shaft Surface	Orbiting Bearing	OK	OK
	Main Bearing	OK	OK
	Sub Bearing	OK	OK
Wear	Orbiting Bearing	OK	OK
	Main Bearing	OK	OK
	Sub Bearing	OK	OK
Oldham Coupling ring	Ring	OK	OK
	Frame	OK	OK