1994

Study of Technology for Refrigerant Applications 2

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Study of Technology for Refrigerant Applications
2. Lubrication of Rotary Compressor in HFC-based Alternates

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Abstract

Long term reliability of rotary compressor in HFC refrigerant systems is mainly dependent on lubrication of moving parts in compressor. To maintain better reliability, basic components in rotary compressor, such as refrigeration lubricant, metallic materials and oil supply systems, were evaluated. A new materials, which are compatible in HFC systems, were determined. Also the results of an accelerated life test of rotary compressor using new materials will be presented.

Introduction

Due to the nature of high efficiency of rotary compressor, they are widely used for home appliance applications, such as room air conditioners, large refrigerators and dehumidifiers *(1)*. Without sacrifice high efficiency of rotary compressor, technical problems associated with lubrication in alternative refrigerants should be made clear.

A completely new materials technology to improve long term reliability of rotary compressor, particularly lubrication, is described in this paper.

Tribology of Rotary Compressor

(1) Lubrication in Liquid Refrigerants, Lubricants and their Mixtures

To study the lubrication in alternative refrigerant systems, the friction test using actual shaft and roller materials to measure both extreme pressure and wear amount was performed *(2)*. The extreme pressure was determined at the point where the friction coefficient was suddenly increased. At this point, gradually increased load causes adhesive wear. Because wear amount at the shaft material was large enough to measure so that this amount was chosen to compare the relative lubricity. Some of test results are shown in Figures 2 and 3.

The order of lubricity in terms of extreme pressure and wear amount are summarized below.

(a) Liquid Refrigerants

Extreme Pressure: 22 > 12 >> 134a > 32
Wear: 32 ≥ 134a >> 12 > 22

(b) Lubricants

Extreme Pressure: POE-56 ≥ POE-32 > POE-15 > HAB-56
Wear: HAB-56 ≥ POE-15 > POE-32 ≥ POE-56

(c) Refrigerant and Lubricant Mixtures

Extreme Pressure: 134a/POE-15 > 22/HAB-56 > 12/HAB-56 > 32/POE-32 = 32/POE-56

Wear: 32/POE-32 > 32/POE-56 > 134a/ POE-15 > 12/HAB-56 > 22/HAB-56

where 12: CFC-12, 22: HCFC-22, 134a: HFC-134a, 32: HFC-32,
POE-15: Polyol ester VG 15, HAB-56: Hard Alkylbenzene VG 56.

In general, HCFCs or CFCs have better lubricity than HFCs. Since HFCs do not have chlorine atom, which would react with iron surfaces to form ferrous chloride layers, lower extreme pressure is expected in HFCs. Therefore following precautions are needed to be considered.

(i) The lubricant concentration in lubricant-refrigerant mixture should be kept greater than 50% in order to supply enough lubricant to compressor moving parts.
(ii) Selection of new materials, which can survive in HFC systems.
(iii) Selection of POE base stock which has better lubricity.

(2) Corrosive Wear

Polyol esters (POEs) are thought to be the best refrigeration lubricants in HFC systems; however, the formation of acidic products by hydrolysis, oxidation or thermal decomposition of POEs is concerned. Although the acid formation can be minimized, described in previous paper, Falex wear test in acidic media is carried out to investigate the effects of acid. The corrosive wear test was utilized in lubricant with known TAN, prepared by adding the same carboxylic acid as POE produces. Two V-blocks and a journal were immersed in the lubricant and 150lb of load was applied. Test results are shown in Figure 4. The wear amount of V-blocks is proportional to the TAN. This suggests that the presence of acids accelerates corrosive wear. Again the wear amount of journal was negligible in this test.

(3) New Materials for Moving Parts

In boundary lubrication regime, direct contact between vane and roller surfaces is occurred. The nature of initial wear of vane and roller in rotary compressors has been well demonstrated but less attention was paid for the difference between various materials. To survive in severe conditions like boundary lubrication, development of new materials was required. In this section, several new materials for vane and roller, listed in Tables 1 and 2, are discussed. The results are shown in Figures 5 and 6. The order of extreme pressure is shown below.

(a) Vane Materials

Extreme Pressure: SKH51 < Hard Metal A < Hard Metal B < C/Al complex

The oxynitriding (ONO) surface treatment dramatically improves extreme pressure shown in Figure 5.

(b) Roller Materials

Extreme Pressure: FCC250 < FCMNC < FCCVB

Increasing primary carbide and steadite quantity is effective to gain better material properties.

(4) Refrigeration Lubricants

Chemistry of refrigeration lubricant in working condition was investigated using a home-made test apparatus, which duplicates actual working conditions. A schematic diagram of apparatus is shown in Figure 7. A rolling roller was placed between two vanes and the load(F) was applied to two vanes. Lubricant was supplied onto roller/vane contacting parts directly by dropping lubricant droplets.

The results are shown in Figure 7. There are liner relationship between friction coefficients and the TAN, and also the consumption of acid catcher. This can be explained by the formation of acids at sliding part of roller and vane, where heat is generated. And formed acids are eliminated by acid catcher. This subtle reaction may lead serious destruction of compressor in long term use. To avoid this reaction, better lubricant supply system, lower friction at sliding parts and selection of thermally stable lubricant are desirable.

Compressor Reliability Test

The rotary compressor drop-in tests, using new materials mentioned above, were performed. The rotary compressor applied was 0.75kW and used for air-conditioner and HCFC-22 alternative refrigerants were examined. The test was carried out under high pressure and speed condition (ie. discharge pressure: 3.04MPa, suction pressure: 0.59MPa, driving speed: 4,000 to 5,700rpm). The wear amount of vane and roller is shown in Figure 8. The order of wear is;

FCMNC/SKI51(Sulphonitriding) > FCCVB/Hard Metal A (oxynitriding)
> FCCVB/C-Al Complex

Also increasing both lubricant viscosity (from VG 32 to 56) and amount of acid catcher reduces wear amount into 10 times less. Confirming above findings, much longer term life tests are in progress.

Conclusions

(1) No benefit of chlorine from HCFC-22 or CFC-12 toward better lubrication is expected. To maintain good lubrication, oil supply to compressor parts is important, keeping greater than 50% oil concentration in oil/refrigerant mixture.

(2) Microscopic corrosive wear was identified under severe roller-vane contacting conditions.

(3) New materials for roller (FCCVB) and vane (Hard Metal B or C/Al Complex) were developed and wear loss was dramatically reduced.

(4) The combination of new materials and POE VG 56 with acid catcher was proven to be the best one by the accelerated life test of compressor.

References

1.(a) K. Matsubara et al.," CFC Issue in Hitachi", Hitachi Review, **39** (6) 1990.

(b) T. Takagi et al.," Development of Substitutes for Ozone Layer-Destroying CFCs", Hitachi Review, **43** (6) 1993.

2. T. Iizuka et al., " Improvement of Reliability of Compressors for Domestic Refrigerators Using HFC-134a ", Proc. Int. Compressor Engg. Conf at Purdue, Vol.3, 1992.

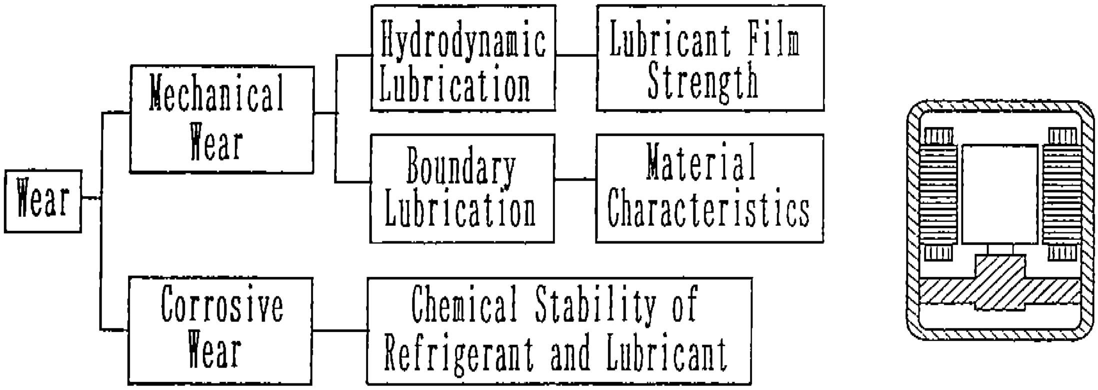


Fig.1 Tribological Issues of a Rotary Compressor

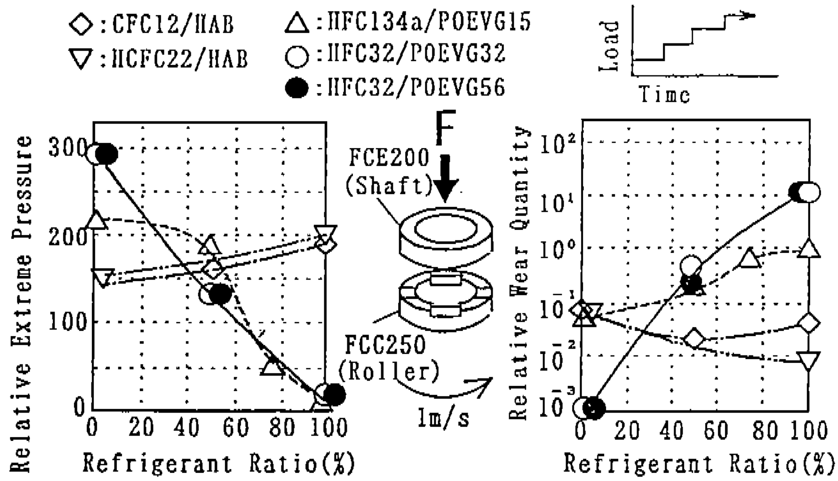


Fig.2 Lubricity of Alternative Refrigerants(Extreme Pressure)

Fig.3 Lubricity of Alternative Refrigerants(Wear Quantity)

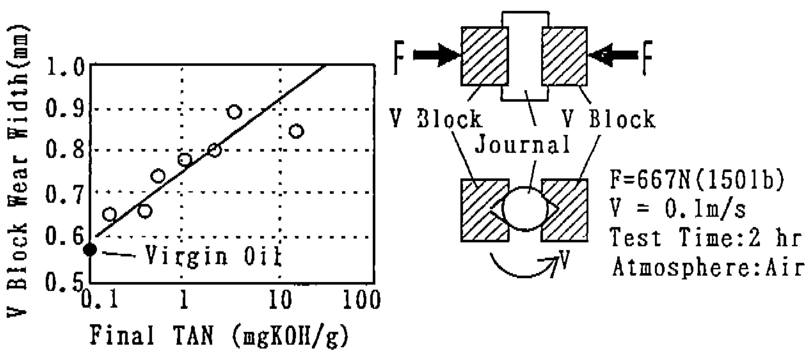


Fig.4 TAN Effect to Wear (Falex Test)

Table 1 Composition of Materials for Roller

Roller Mat.	C (%)	Other Composits									HRC	P.C.& S. (%)*
FCC250	3.48	Si	Mn	P	S	Ni	Cr	Mo	Ti	—	57.0	1.0
FCCVB	3.33	Si	Mn	P	S	Ni	Cr	Mo	—	B	57.0	5.8
FCMNC	3.10	Si	Mn	P	S	Ni	Cr	Mo	—	—	53.2	1.5

*Primary Carbide and Steadite Quantity

Table 2 Composition of Materials for Vane

Vane Mat.	C (%)	Other Composits									HRC
SKH51	0.89	Si	Mn	Cr	W	Mo	V	Co	—	—	59.0
Hard Metal A	2.14	Si	Mn	Cr	W	Mo	V	Co	—	—	66.5
Hard Metal B	3.49	Si	Mn	Cr	W	Mo	V	Co	Ti	—	73.2
C/Al Complex	44.6	Si	—	—	—	—	—	—	—	Al	19.0

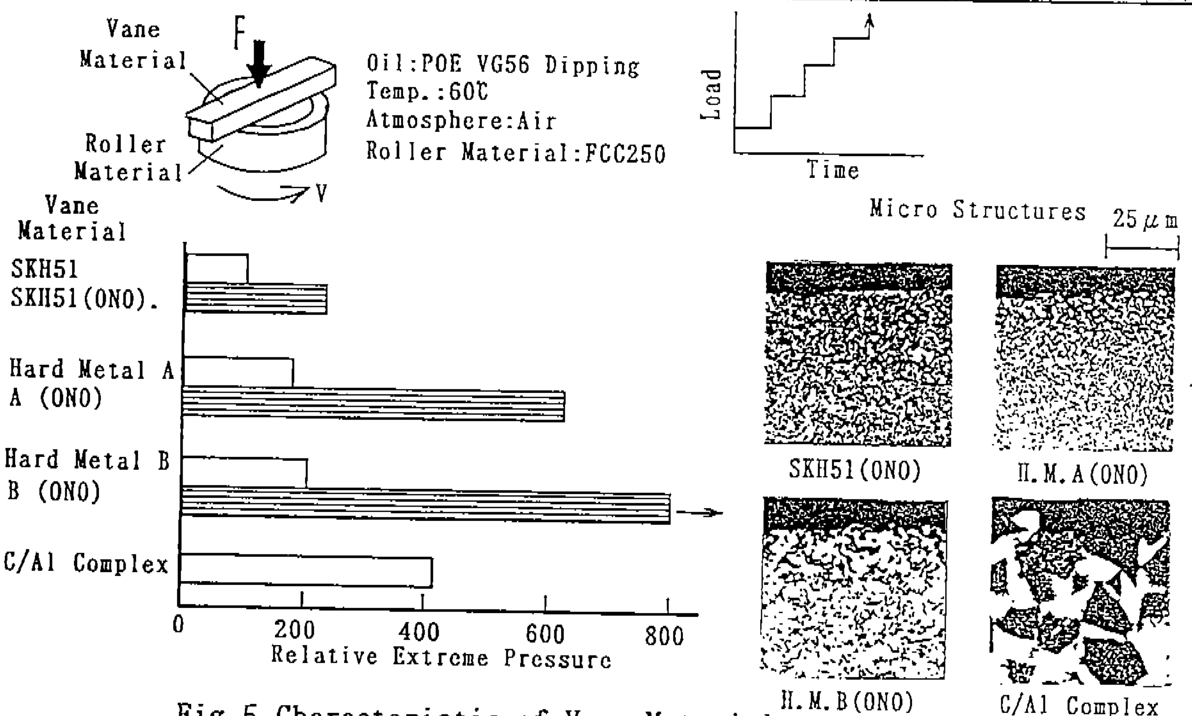


Fig.5 Characteristic of Vane Material

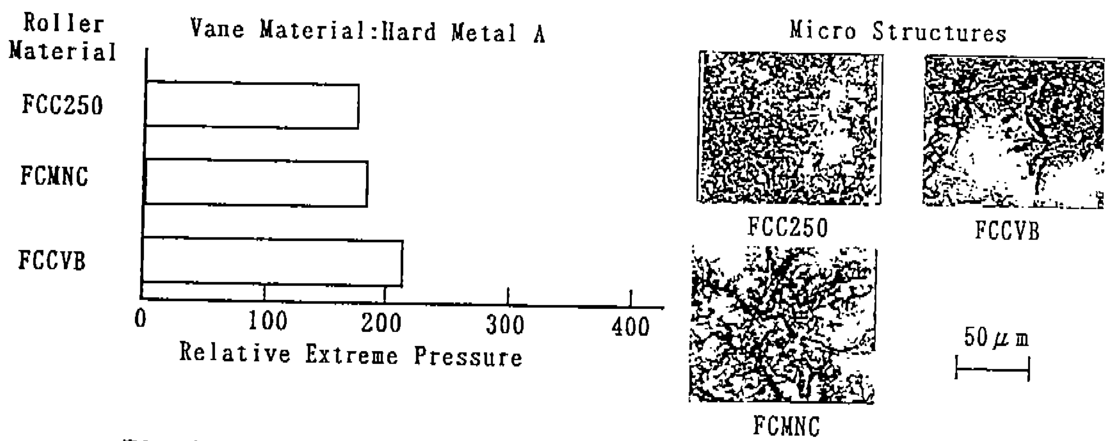


Fig.6 Characteristic of Roller Material

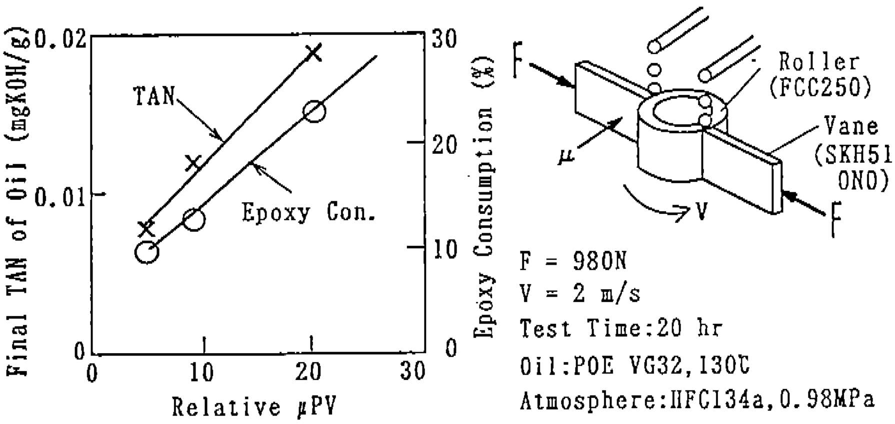
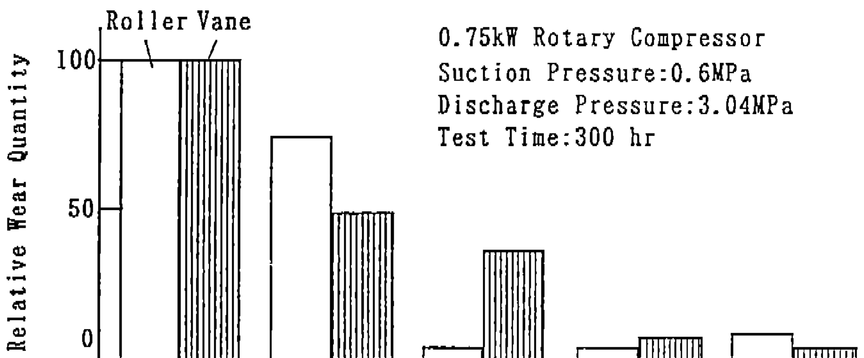


Fig.7 Behavior of TAN and Epoxy in POE Oil



Roller		FCMNC	FCCVB	←	←	←
Vane		SKH51	Hard Metal A (ONO)	C/Al Complex	Hard Metal A (ONO)	C/Al Complex
POE Oil	VG	32	←	←	56	←
	Add.*	100	←	←	200	←
Refrigerant		HFC32/134a	←	HFC32/125/134a	HFC32/134a	HFC32/125/134a

*Add.:Relative Content of Epoxy

Fig.8 Result of Accelerated Test for Rotary Compressors