International Refrigeration and Air Conditioning Conference

School of Mechanical Engineering

2010

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ABSTRACT

Improvement of energy efficiency is one of the effective methods for global environment protection. Using lower viscosity oil is known as an effective method, especially for small reciprocation compressors. Recently, it is attracted attention to use lower viscosity oil for hydrocarbon refrigerant applications. In this study, research and examination results about the development of low viscosity oils (lower than VG7) were reported.

In general, the use of lower viscosity oil will be resulted in improvement of lubricity. However, there are other considerable problems, such as flash point, stability of base stocks, material compatibility (especially for organic materials), and refrigerant compatibility. Each problem was examined and extreme low viscosity oils, such as VG5 mineral oil, VG3 and VG5 ester oils were developed.

1. INTRODUCTION

Refrigeration oil has been changed with the change of refrigerant because it was used under the refrigerant atmosphere. As a refrigerant for initial domestic refrigerator, R12 which was Freon refrigerant without the toxicity and flammability was used. However, R12 was regarded as the causative agent of the ozone depletion, R134a which did not contain chlorine, came to be used mainly in place of R12 after Montreal Protocol in 1987. For Freon refrigerant mineral oil was used, but as for R134a refrigerator, POE (Polyol Ester) was developed because R134a did not miscible with mineral oils. Since 1997, HFC refrigerant had been regulated for its high GWP value. From then on, natural refrigerant was attracted attention as environmentally-friendly refrigerant in Japan and Europe. For a home refrigerator, R600a (hydrocarbon refrigerant) was adopted and this refrigerator was marketed as a non-HFC Refrigerator from 2002.

Recently, R600a with mineral oil is chiefly used for home refrigerator in Japan, and the switch to R600a is advanced also in Asia. Meanwhile, R134a with ester oil is used mainly in North America because of the flammability of R600a.

2. CURRENT SITUATION OF THE LOW VISCOSITY OIL

For R134a compressor, there are two types of POE as low viscosity refrigeration oil. One is VG8 POE that is made from branch type fatty acid, the other is VG7 POE that made from linear type fatty acid. For R600a compressor, mineral oils (VG10 to VG22) have been used mainly and recently the mineral oil of VG8 was developed and used actually. To improve the energy efficiency of R600a compressor, the refrigeration oil that has the viscosity lower than VG7 is investigated and developed.

3. Difficulties in development of low viscosity refrigeration oils

In general, the use of lower viscosity oil will be resulted in improvement of lubricity. However, there are other considerable difficulties to solve, such as flash point, stability of base stocks, material compatibility (especially for organic materials), and refrigerant compatibility.

3.1 Flash point

The flash point of compounds tends to lower with small molecular weight because it is a character which relates closely to the vapor pressure of the liquid. Thus, the flash point of lower viscosity oil decreases if it is the same kind of lubricant. For example, the flash point of praffinic refrigeration oil is about 180 degree C for VG22, 170 degree C for VG15, and 160 degree C for VG10. The flash point lowers as the viscosity decreases, therefore the flash point is one of the difficulties to develop a low viscosity oil. And there is a possibility to influence oil purifier because low boiling point component increases as the flash point decreases. Though it is necessary to keep constant vacuum level of the oil purifier, it becomes impossible to maintain the vacuum level as the low boiling point component increases. Therefore high flash point oil is preferable.

On the other hand, ester oils have relatively high flash point, thus this difficulty is not so severe for ester oils.

3.2 Stability

In the case of ester base stock, the stability should be considered. The size of the molecule of the oil becomes smaller as the viscosity decreases. As generally known, the reactivity of organic compound rises, when its carbon chain become shorter. To realize low viscosity with POE structure, very short chain fatty acids have to be utilized and this causes stability worse.

Moreover, the influence on the materials in the compressor is feared. Concretely, a metallic material is corroded, the organic materials deteriorate, and the amount of the oligomer extracted from organic materials will increase. The oligomer may cause the trouble of the discharge valve and the capillary tube.

3.3 Lubricity

The use of the lower viscosity oil influences not only directly but also indirectly because the refrigeration oil is used under the refrigerant atmosphere. In the compressor, refrigerant dissolves to oil and the effective viscosity of oil-refrigerant mixture lowers more than the viscosity of the oil. The effective viscosity is decided by the amount of refrigerant dissolution and the rate of the viscosity reduction in dissolving of the refrigerant. The decrease of lubricity by the effective viscosity reduction is feared.

4. Development of low viscosity refrigeration oils

4.1 Flash point

It was necessary that the flash point should not be below 120 degree C. Therefore, the target value of the flash point was set with more than 130 degree C from the viewpoint of safety.

Table 1 shows properties of VG5 experimental oils. Though the flash point of experimental oil 1 was about 120 degree C, while that of experimental oil 2 which used different base stock was more than 130 degree C. Therefore experimental oil 2 was adopted as VG5 mineral refrigeration oil. However, in the case of mineral oil , it is thought that VG5 is the lowest viscosity in practical use because it is expected that the flash point becomes less than 120 degree C when the viscosity is lower than VG5.

4.2 Stability

As a candidate of the synthetic oil, POE which was used for HFC refrigerants was evaluated.

Table 2 shows the result of stability of the low viscosity POE oil evaluated by autoclave test. The acid value of the low viscosity POE oil increased greatly by the autoclave test. It indicated that the stability of the low viscosity POE decreases because of high reactivity of very short chain fatty acids.

It was found that maintaining enough stability as a refrigeration oil is difficult for POE type low viscosity oil, and new synthetic oil started to be evaluated. As the result of stability of the new synthetic oil, enough stability as a refrigeration oil was found even if the viscosity is lowered to about VG3.

4.3 Lubricity

Lubricity was evaluated by FALEX extreme pressure test. Though the decrease of lubricity was feared the mineral oil with extreme pressure agent and the new synthetic oil indicated the lubricity of the same level as current products (shown in figure 1).

And the amount of dissolution of R600a to the low viscosity refrigeration oil and the viscosity of oil and refrigerant mixture were measured. The amount of R600a dissolution was VG5 mineral oil, VG8 mineral oil (current product for R600a), and VG5 new synthesis oil in a lot of order. It was thought that the amount of R600a dissolution to VG5 mineral oil increased because it became easy for the refrigerant to dissolve in lower viscosity oil. It is necessary to evaluate the lubricity when the refrigerant dissolves by the test using actual compressors or refrigerating machines.

5. Conclusion

There were several difficulties in the development of low viscosity oils less than VG7. However, as a result of this study, these difficulties were solved and three extreme low viscosity oils were developed (shown in Table 3). For the next step, actual performance has to be evaluated, through the test using actual compressors or refrigerating machines.

Table1 Properties of VG5 experimental oil

			Experimental oil 1 VG5	Experimental oil 2 VG5	Current product VG8
Flash point	COC	℃	120	136	160
Kinematic Viscosity	40 degree C	mm^2/s	5.1	5.2	7.7
	100 degree C	mm^2/s	1.7	1.7	2.2

Table2 The result of autoclave test of the low viscosity oil

			POE VG5	POE VG8	New synthetic oil VG5
Kinematic Viscosity	40℃	mm^2/s	4.5	7.4	5.2
	100℃	mm^2/s	1.6	2.0	1.7
Acid value (after aging by autoclave test※)		mgKOH/g	0.27	0.03	0.03

※Autoclave test condition: Oil/R600a=30g/10g, Fe,Cu,Al, 175 degree C×14days

Table3 Properties of low viscosity oils

			Mineral oil VG5	New synthetic oil VG3	New synthetic oil VG5
Color	ASTM		L0.5	L0.5	L0.5
Density	15 degree C		0.85	0.87	0.90
Flash point	COC	℃	136	154	168
Kinematic Viscosity	40 degree C	mm^2/s	5.2	3.2	5.2
	100 degree C	mm^2/s	1.7	1.3	1.7
Acid value		mgKOH/g	0.01	0.01	0.01
Pour point		℃	-40	<-50	<-50
Miscibility※			<-40	<-40	<-40
Acid value (after aging by autoclave test)		mgKOH/g	0.01	0.03	0.03
FALEX Extreme pressure		N	2180	2220	2440

※Miscibility: Oil/R600a=1/9

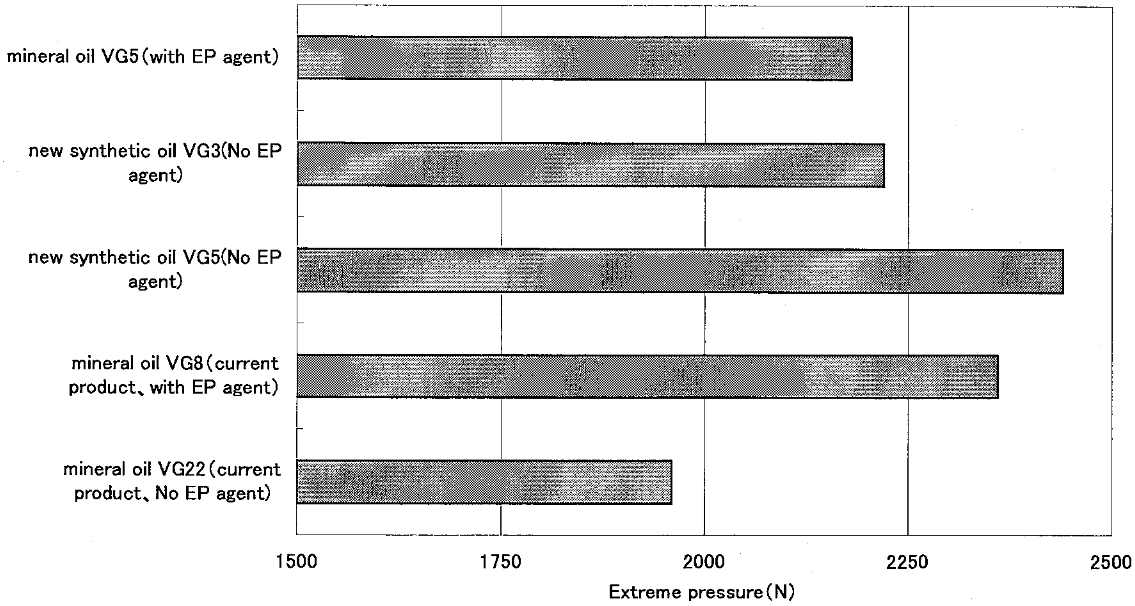

Figure1. The result of FALEX extreme pressure test