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LIQUID REFRIGERANT MIGRATION CONTROL BY USING AN OIL HEATER AND ITS EFFECTS ON MIXTURE MISCIBILITY AND VISCOSITY

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ABSTRACT

The solubility of fluorinated refrigerants in lubrication oil affects not only the stability performance of vapor compression refrigeration system, but also the safety control of start-up. It can cause oil foaming and reduction of viscosity, resulting in liquid slugging and improper lubrication. To void the deleterious effects, an oil heater is often used. But improper heater power can cause oil overheat. In this paper, the effects of heater power on miscibility and viscosity of refrigerant/oil mixture were calculated on basis of analyzing heat flow of a compressor and employing empirical correlation.

Key words: compressor, refrigerant, oil, mixture, viscosity, miscibility

NOMENCLATURE

Ts	Temperature of refrigerant vapor, K
Tsw1	Temperature of shell wall upper oil surface, K
Tsw2	Temperature of shell wall under oil surface, K
Tcom	Temperature of compressor material, K
Tso	Ambient temperature, K
q	Power of oil heater, W
Rolf	Thermal resistance between oil and refrigerant vapor W/m^2
Rcof	Thermal resistance between refrigerant vapor and compressor material, W/m^2
Rswf	Thermal resistance between refrigerant vapor and compressor shell, W/m^2
Rcol	Thermal resistance between oil and compressor material, W/m^2
Rolw	Thermal resistance between oil and compressor shell, W/m^2
Rcsw	Thermal resistance between compressor shell and inner material, W/m^2
Rswo	Thermal resistance between compressor shell and ambient, W/m^2
μ	viscosity, centipoise, cp
p	Absolute pressure, MPa
DL	Density of the liquid, g/mL
C	Mass fraction of refrigerant in the liquid
T	Temperature, K
A_0~A_8	Coefficients for empirical correlations of viscosity
B_0~B_8	Coefficients for empirical correlation of pressure
D_0~D_8	Coefficients for empirical correlation of density

INTRODUCTION

Refrigerant vapor will always migrate to the coldest part of the system, and if the off cycle extend several hours or more, the compressor shell can become colder than other parts of the system, refrigerant in the condenser, receiver, and evaporator will vaporize, travel through the system, and condense in the compressor shell. The liquid refrigerant will dissolve in oil.

R12 and certain other refrigerants, are totally miscible with oil. For this mutual miscibility refrigerant and oil mixture, when compressor start, with the decrease of pressure in compressor shell, the refrigerant storage capacity of oil reduces, which results in formation of refrigerant vapor bubbles around the nucleation centers in the oil. The vapor bubbles, once formed, rise and break away from the oil surface. The sizes and shapes of vapor bubbles departing from the oil surface depend on the mass flow rate of vapor leaving the oil surface. If the mass flow rate is very low, the bubbles at the oil surface will burst open and only the vapor refrigerant will flow into the suction chamber. If the refrigerant mass flow rate is high enough, refrigerant vapor bubbles will pile up in the free volume of shell, resulting in the flow of lubricating oil into the compressor cylinder, it may damage compressor due to liquid slugging[1].

For partial miscible refrigerant, oil-rich and refrigerant-rich phases may exist, oil floats on top of the refrigerant and the oil pump inlet at the bottom of sump is fed almost pure refrigerant at start-up. The resulting improper lubrication can result in bearing failure.

So, refrigerant migrate to compressor and dissolved in oil is very danger to start-up of compressor. One practicable means of protecting against migration and dissolve of refrigerant is the using of oil heater. By warming the oil, the temperature in compressor shell will be higher than the coldest part of the system. Refrigerant entering the compressor shell will then be vaporized and driven back into the suction line. On the other hand, higher oil temperature makes the miscibility of refrigerant in oil minimized, retards the oil foaming. Crankcase heater is often installed under the oil surface in open-type compressor, and a trap heater is equipped around the down shell for hermetic reciprocation compressor. But improper size of heater can overheat the oil, resulting in the decreasing viscosity or even carbonize the oil. The effects of heater power on miscibility and viscosity of refrigerant/oil mixture are calculated on basis of analyzing heat flow of a compressor and employing empirical correlation. It presents an approach to select proper oil heater power.

MODELING

Figure 1 illustrates the conceptual model of the compressor shell. An oil heater is equipped under the compressor shell. For effective protection, the oil heater must be energized several hours before starting the compressor. So the compressor is assumed in stable state. Adopting lump parameters modeling, we can write down the heat balance equations of refrigerant vapor, the oil, compressor material, shell wall material upper oil surface and under oil surface.

$$\frac{T_{oil}-T_s}{R_{olf}}+\frac{T_{com}-T_s}{R_{cof}}+\frac{T_{csw}-T_s}{R_{swf}}=0 \qquad (1)$$

$$\frac{T_{com}-T_{oil}}{R_{col}}+\frac{T_{sw2}-T_{oil}}{R_{olw}}+\frac{T_s-T_{oil}}{R_{olf}}=0 \qquad (2)$$

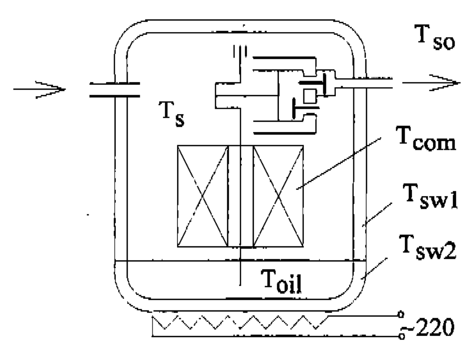

Fig. 1 Compressor shell model

$$\frac{T_{sw2}-T_{sw1}}{R_{w12}}+\frac{T_{com}-T_{sw1}}{R_{csw}}+\frac{T_{so}-T_{sw1}}{R_{swo}}+\frac{T_s-T_{sw1}}{R_{swf}}=0 \quad (3)$$

$$\frac{T_{so}-T_{sw2}}{R_{swo}}+\frac{T_{oil}-T_{sw2}}{R_{olw}}+\frac{T_{sw1}-T_{sw2}}{R_{w12}}+q=0 \quad (4)$$

$$\frac{T_{oil}-T_{com}}{R_{col}}+\frac{T_s-T_{com}}{R_{cof}}+\frac{T_{sw1}-T_{com}}{R_{csw}}=0 \quad (5)$$

Ts, Toil, Tsw1, Tsw2, Tcom can be solved from above equations if the thermal resistances between the various temperature nodes were obtained. It must mention that to calculate the thermal resistance of each point, Ts, Toil, Tsw1, Tsw2, Tcom must be known to determined parameters in heat transfer coefficients. So Ts, Toil, Tsw1, Tsw2, Tcom should be set primary values and obtained through iteration. Repeat above procedure, we can obtain different oil temperature Toil at different power of oil heater. Pressure in compressor shell is assumed at stature pressure of refrigerant at ambient temperature, it also is the mixture pressure. The concentration, viscosity and density of refrigerant/oil mixture are obtained from empirical correlation[2].

$$P = B_0 + B_1C + B_2T + B_3CT + B_4C^2 + B_5C^2T + B_6CT^2 + B_7T + B_8C^2T^2 \quad (6)$$

$$\log_{10}(\mu) = A_0 + A_1C + A_2T + A_3CT + A_4C^2 + A_5C^2T + A_6CT^2 + A_7T^2 + A_8C^2T^2 \quad (7)$$

$$D_L = D_0 + D_1C + D_2T + D_3CT + D_4C^2 + D_5C^2T + D_6CT^2 + D_7T^2 + D_8C^2T^2 \quad (8)$$

where $T=T_{oil}/293.15$

RESULTS AND DISCUSSIONS

The mathematical model was applied to calculate a hermetic reciprocating compressor, which charged with R22 and 150 SUS Naphthenic oil.

Figure 2 is a plot of the temperatures of refrigerant vapor, oil, compressor shell under oil surface and upper oil surface vs. power of oil heater. It shows that temperatures increased with increasing heater power.

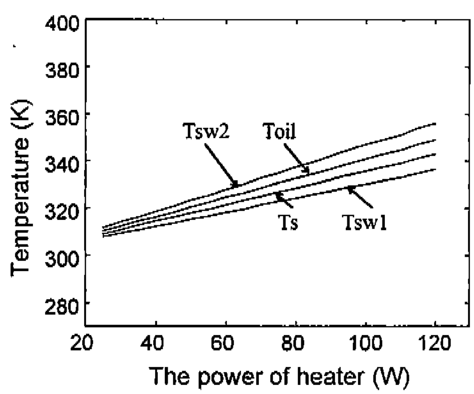

Fig. 2 Temperatures variation with power of oil heater

Figure 3 shows that the concentration of refrigerant decrease as the input heater power increases. It can conclude that using an oil heater is an efficiency method to reduce concentration of refrigerant in oil.

Figure 4 shows viscosity initially increases and then decreases as heater power increases. This is because as heater power increases the oil temperature increases, the concentration of refrigerant in the oil reduces. Since the refrigerant viscosity is typically 2~3 order of magnitudes smaller than that of oil, the viscosity increase caused by reduction of refrigerant concentration is dominant factor. However, when the concentration of refrigerant is low, mixture's behave tend to pure oil, the viscosity decreases as temperature increases, and this effect eventually overcomes the earlier effect that has caused the viscosity to increase.

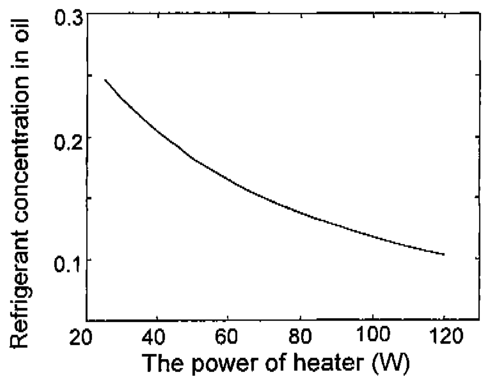

Fig. 3 Concentration of refrigerant variation with power of oil heater

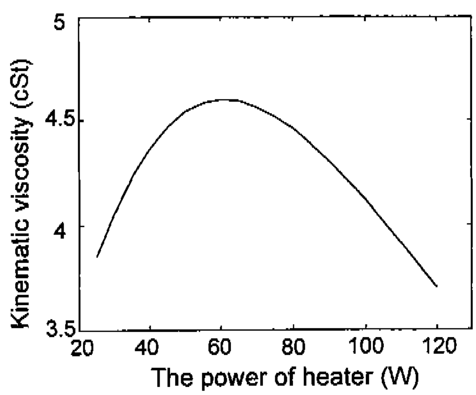

Fig. 4 Viscosity variation with power of oil heater

SUMMARY

Based on analyzing the heat flow of a compressor and employing empirical correlation., a method was developed to predict the concentration of refrigerant and viscosity of refrigerant/lubricant mixture by a given heater power.

Using oil heater to retard liquid refrigerant migration and reduce concentration of refrigerant in oil is very effective. However, considering the viscosity and chemical stability of oil, the power input of oil heater must be limited to maintained a proper oil temperature.

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