Assuring Reliability of Compressors Using HFC Refrigerants

By Hideto NAKAO
Mitsubishi Electric Corporation
Amagasaki-City, Hyogo, Japan

Abstract

In Japan, the refrigerant used in room air-conditioners has been changed from HCFC-22 (R-22) to R-410A, a blend of HFC-32 and HFC-125 (50/50 vt%), in order to protect the ozone layer. Generally, the miscibility between the refrigerant and refrigeration oil must be assured, because the oil needs to return to the compressor from the refrigeration cycle and lubricate the sliding parts. Alternative oils with good miscibility with HFCs have been developed, because mineral oil, the primary oil used with R-22, has low miscibility with HFC. The chlorine atoms which make up R-22 create excellent extreme pressure performance on the sliding parts in compressors; however, they are the cause of the depletion of the ozone layer. Because HFC does not have any chlorine atoms in its molecular structure, it is essential to prevent the sliding parts from scuffing (seizing) and wearing when using HFC in the compressors,. Therefore, anti-wear additives are added to the oils, and alternative sliding materials and surface treatments have been used in rotary, swing and scroll compressors which are fitted to room air-conditioners in Japan. The problems in using HFC in swing compressors are similar to those for rotary compressors. This paper describes the technical problems of ensuring the reliability of rotary and scroll compressors using R-410A.

Background

Both rotary compressors and scroll compressors use HFC refrigerants. In Japan air-conditioners, including room air-conditioners, packaged air-conditioners and multi air-conditioners for buildings, and refrigeration machines all use HFC refrigerants.

Description of Compressors

Figure 1 presents the cross-section views of rotary compressor. The main sliding parts in a rotary compressor are the sliding bearings, located at the upper and lower ends of the cylinder and supporting the crankshaft, and the vane tip in the cylinder. The suction gas is compressed until reaching the required pressure in the cylinder and discharged to the inside of the shell and then discharged to the refrigeration cycle from the discharge port. The reliability of the sliding bearing is ensured by maintaining the viscosity of the oil mixed with the refrigerant and the film thickness under operating conditions. However, the vane tip contacts the outside surface of the rolling piston linearly and high contact pressure is loaded between the two parts and the outside surface of the rolling piston slides on the vane tip. Therefore, anti-wear technology is required for the vane tip.

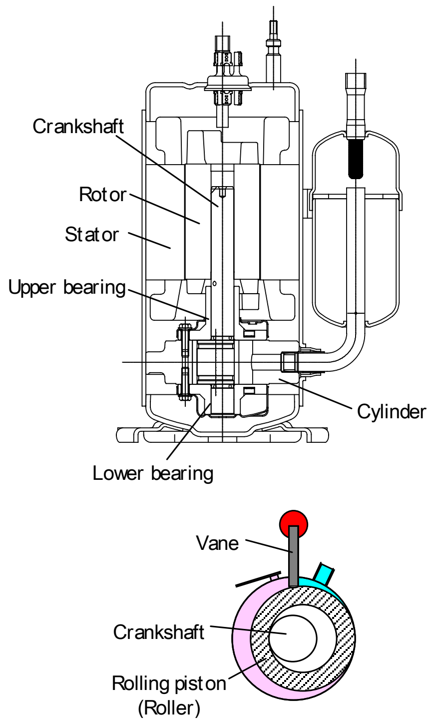

Fig. 1 Cross-section view of rotary compressor

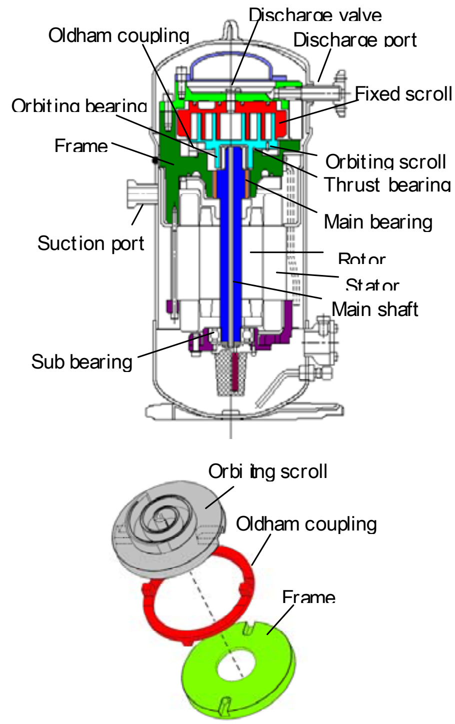

Fig. 2 Cross-section view of scroll compressor

Figure 2 presents the cross-section views of a scroll compressor. The main sliding parts in a scroll compressor are the main and sub bearings supporting the main shaft, the orbiting bearing supporting the orbiting scroll, the Oldham coupling converting the rotating motion of the main shaft to the orbiting motion of the orbiting scroll and the thrust bearing supporting the axial compression load of the orbiting scroll. The suction gas is compressed until reaching the required pressure in the spaces between the fixed scroll and the orbiting scroll and discharged to the refrigeration cycle from the discharge port. The reliability of the sliding bearing is ensured by maintaining the viscosity of the oil mixed with the refrigerant and the film thickness under operating conditions. However, especially the Oldham coupling reciprocates on the undersurface of the orbiting scroll and the top surface of the frame and the oil film is not able to form. Therefore anti-wear technology is also required in scroll compressors.

Characteristics of Alternative

Table 1 shows the characteristics of R-22 and R410-A. The chlorine atoms in R-22, form a chloride film on the sliding surfaces. The chloride film has extreme pressure performance. However, the operating pressure of R-410A is about half as high as

Table 1 Characteristics of refrigerants

Refrigerant	HCFC	HFC
	R-22	R-410A
components	-----	HFC32/125
(ratio, wt%)	-----	(50/50)
zeotropic /azeotropic	single	near azeotropic
ODP	0.055	0
GWP (100 years)	1700	1700
condensation pressure, MPa (40℃)	1.53	2.41

that of R-22 and the pressure tightness of the shell needs to be enhanced when using R-410A. Because R-410A has the highest performance of HFC refrigerants, R-410A was selected as the replacement for R-22 in newly manufactured equipment. Mineral oil, the primary oil used with R-22, has low miscibility with HFCs; therefore, ester and ether oils, which are highly miscible with HFCs, have been developed. However, anti-wear additives must be added to these oils and new sliding materials and surface treatments must be used because HFCs do not have any chlorine atoms in their molecular structure to form a film on sliding surfaces. In addition, wear and scuffing of the sliding parts need to be prevented by anti-wear additives. When the atmospheric temperature is low in winter, the liquid refrigerant dissolves in the oils and the viscosities of ester and ether oils are lowered. Therefore, alkyl benzene which has low miscibility with HFC has been used.[1,2]

Identifying the Appropriate Anti-Wear Additives for R-410A

Figure 3 presents the relationship between the quantities of the anti-wear additives in the ester oil and the scuffing pressure of cast iron in a HFC atmosphere.[3] When the optimum quantities of additives are added to the ester oil, the scuffing pressure reaches the highest value.

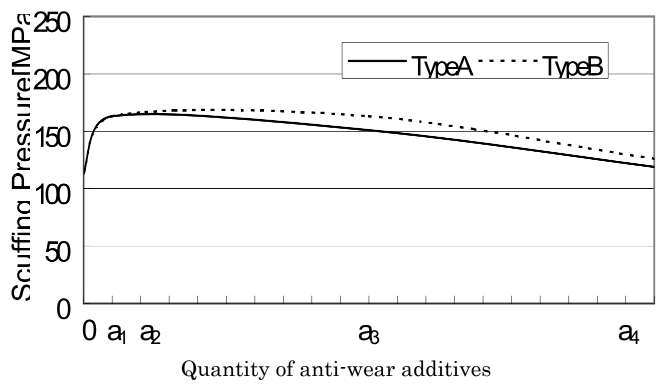

Fig. 3 Relationship between quantities of anti-wear additives and scuffing pressure

Figure 4 presents the wear amounts of the vane and rolling piston (roller) in the rotary compressors lubricated by R-22 and mineral oil, compared to R-410A and ether oils.[4] When surface treated high speed steel is used for the vane, the amount of wear of the roller is reduced.

Figure 5 presents the wear depth of the sliding bearing material using R-410A and alkyl benzene compared to the wear depth of R-22 and mineral oil and R-410a and polyester oil. The wear depth for R-410A and alkyl benzene is lower than that using R-22 and mineral oil, or R410A and ester oil.[1] However, a special oil returning mechanism is needed in

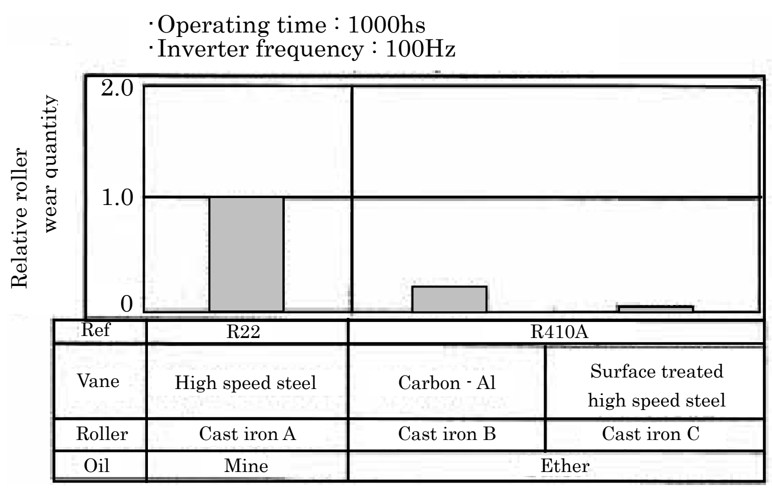

Fig. 4 Comparison of roller wear

order to use alkyl benzene as the refrigeration oil for HFCs.[2]

A wear reduction method is also needed for scroll compressors using HFCs.[5, 6] There is concern regarding the Oldham coupling wear in the scroll compressor. Figure 6 shows the result of a wear test using gray cast iron (FC250) and the Oldham coupling material.[6] An Oldham coupling made from sintered iron without surface treated is not able to reduce the amounts of wear. However, when sintered iron treated by steam treatment and gas nitro-carburizing, the amounts of wear are reduced.

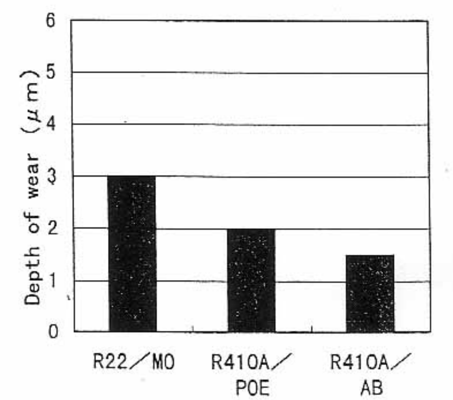

Fig. 5 Wear depth of shaft after flooded-start test

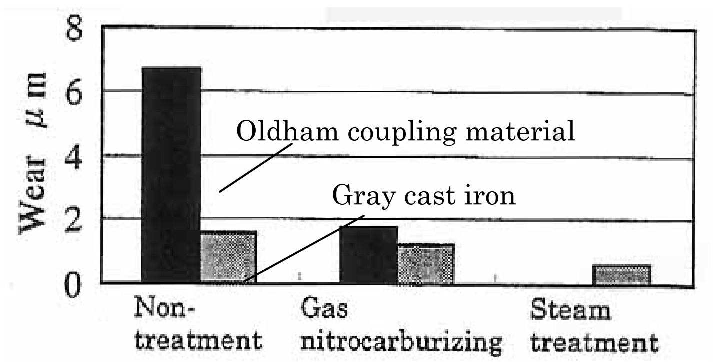

Fig. 6 Wear amounts of Oldham coupling

Impact of Switch to Alternative

The manufacturing costs increase when changing the refrigerant from HCFC to HFC because the refrigeration oils are changed from mineral oil to ester and ether oils, and surface treatments and alternative materials to be used for the sectional sliding parts and the pressure tightness of the shell needs to be enhanced. However, the performance of room air-conditioners using R-410A is better than those using R-22. In addition, the operational costs, namely electricity, are the same.

References

1) Shin Sekiya, Yoshinori Shirafuji, Susumu Kawaguchi, Taro Kato, Takeshi Izawa: Alkylbenzenes for Split Air-Conditioners with R410A Part 1: Reliability Evaluation of Compressors, 1998 International Compressor Engineering Conference at Purdue (1998) 465.
2) Yoshihiro Sumida, Masahiro Nakayama, Sou Suzuki, Susumu Kawaguchi: Alkylbenzenes for Split Air-Conditioners with R410A Part 2: Oil Return Characteristics, 1998 International Compressor Engineering Conference at Purdue (1998) 471.
3) Hideto Nakao, Koei Matsukawa, Yoshinori Shirafuji, Shin Sekiya: The Effect of Water Contents of POE on Scuffing Characteristics, 2000 International Compressor Engineering Conference at Purdue (2000) 207.

4) Kazuaki Fujiwara, Kenzo Matsumoto, Takahiro Nishikawa, Takeshi Sato: Performance and Reliability Evaluation of Rotary Compressor for HFCs, The International Symposium on HCFC Alternative Refrigerants ’98 (1998) 145.
5) Hideki Matsuura, Masahiro Minowa, Yukio Fudemato, Susumu Hiodoshi, Masaki Nomura: Evaluation of Refrigerant Oil for HFC Refrigerants and Selection of Sliding Materials, The International Symposium on HCFC Alternative Refrigerants ’98 (1998) 423.
6) Yodhiyuki Futagami, Hideo Hirano, Mototaka Esumi, Hideto Oka, Hiroyuki Kawano, Keizo Nakajima: Development of the Materials for Sliding Part of the Compressor for HFC’s, 1998 International Compressor Engineering Conference at Purdue (1998) 135.