1996

Development of Swing Compressor for Alternative Refrigerants

M. Masuda
Daikin Industries

K. Sakitani
Daikin Industries

Y. Yamamoto
Daikin Industries

T. Uematsu
Daikin Industries

A. Mutoh
Daikin Industries

Development of Swing Compressor for Alternative Refrigerants

Masanori Masuda, Katsumi Sakitani[1], Yasushi Yamamoto
Takahiro Uematsu, Akio Mutoh
Daikin Industries, Ltd.
Compressor Development and Engineering Center
3-12 Chikkou - shinmachi, Sakai
Osaka, 592 Japan
[1]Daikin Industries, Ltd., Mechanical Engineering Laboratory

1. Abstract

In a rotary compressor, we must improve the durability of the lubrication for alternative refrigerants (hydrofluorocarbons), because by changing refrigerants there is a loss of lubricating ability. We have improved the durability by changing from rotary to swing structure, rather than by changing the material of the rotary compressor. This improvement of lubrication can reduce sludge generation, too, and therefore reduce capillary tube clogging. In addition, we have improved the energy performance by changing from rotary to swing structure.

This paper presents the development of the swing compressor for alternative refrigerants and its experimental results.

2. Introduction

Simple structure and high reliability are the two strong points of rotary compressors, which are used in a wide range of operations, especially in small refrigeration systems and air conditioning systems. On the other hand, their structural disadvantage requires solutions for use in alternative refrigerants.

In a rotary compressor, the compression chamber is created by pressing the sliding vane to the roller. At the contact point of the sliding parts, maintaining the layer of oil becomes the key to reliability because it is very difficult to avoid mixed lubrication. In addition, inadequate lubrication causes a partial temperature rise, which then initiates the forming of sludge and clogs the capillary tube.

Alternative refrigerants do not include chlorine atoms in the molecule. Therefore, in the development of alternative refrigerants, mixed lubrication because becomes a serious problem, and we need to take measures to prevent the situation.

In the development of our swing compressor, we improved the weak points of the rotary compressor while maintaining its strong points.

3. Characteristics of Swing Compressor

3.1 Structure

The structure of the swing compressor and rotary compressor are shown in Figure 1. In a swing compressor, the lubrication problem between the sliding vane and roller is eliminated by attaching the vane to the roller. Therefore, the roller is operated without rotation by means of anti-rotation parts, a pair of swing bushes.

This type of compressor, for example the kinney pump of the early 20th century, has been used as an air compressor and vacuum pump for industrial use.

3.2 Reliability

A swing compressor can handle alternative refrigerant by eliminating the contact point between sliding vane and roller. In addition, due to the swing structure, the sliding vane mechanism, which divides the chamber into a compression chamber and suction chamber, becomes a simply-supported-beam type instead of a cantilever type. Therefore, the reaction forces acting on the sides of the vane are drastically reduced. The improvement in lubricating ability reduces the forming of sludge, due to the elimination of temperature rise at the vane-roller contact point.

However, the sliding speed between roller and crankshaft increases. We confirmed this problem by checking the rotary compressor's sliding speed. Roller rotation speeds for a rotary compressor are shown in Figure 2. In a rotary compressor, roller rotation is restricted by the vane top. Rotation speeds are less than 10% of shaft speeds under difficult conditions of lubrication, such as high pressure ratio and low viscosity. Under such conditions, there is no difference in durability between rotary and swing compressors.

3.3 Compressor Performance

3.3.1 Mechanical Loss

We simulated the mechanical loss and compared rotary and swing compressors (see Table 1). Shifting the swing structure adds friction-causing parts, for example the crank-pin bearing (which increases sliding speed) and the new bearings in the swing bushes. However there are friction-reducing parts, too, for example the sliding vane top and side. As a result, total mechanical loss was about 3~4% less than in the rotary structure.

3.3.2 Volumetric Efficiency

The leakage area between the outside wall of the roller and the inside wall of the cylinder is an important factor in volumetric efficiency. However, because of the clearances of the bearings, narrowing the gap is difficult, so an improvement in efficiency could not be realized. In a swing compressor, because the sliding vane and roller are attached, as opposed to a rotary compressor, we could try to improve the efficiency.

At first, we reduced the ratio of leakage area per suction volume, by lowering the height of the cylinder and maintaining the suction volume. However, due to the necessity of increasing eccentricity, maintaining the suction volume becomes a difficult problem for a rotary compressor. The force acting on the side of the vane increases, and this force becomes intolerable because of the cantilever type beam mechanism. Another way to maintain the suction volume is to widen the diameter of the cylinder without increasing the eccentricity. However, to achieve this, the diameter of the roller must be widened too. The weak point of a rotary compressor, the contact point between sliding vane and roller, can not withstand this. In a swing compressor, we were able to lower the height and widen the diameter of the cylinder without increasing these problems. We estimate 30 percent of the leak could be decreased by this method (see Table 2).

Second, we used an oil seal between the outside wall of the roller and the inside wall of the cylinder. Because we had widened the diameters of roller and cylinder, the acting area of the oil seal was therefore also widened. The viscosity produced a good effect on the leakage. We estimate 18 percent of the leak could be decreased by this method (see Table 3).

4. Experiment

4.1 Compressor Performance

The effect of compressor speed on total efficiency and volumetric efficiency of each compressor, swing and rotary, is shown in Figure 4 . It can be seen that in a swing compressor, the total efficiency was 5~9% higher than for a rotary compressor in the middle- to low-speed range and 2% higher in the high-speed range. Therefore, we confirmed that the improvement in the middle- to low-speed range is mainly affected by the volumetric efficiency, and in the high-speed range, is mainly affected by the mechanical loss.

4.2 Reliability

4.2.1 Compressor Durability

We evaluated the durability of compressors using alternative refrigerants (HFC's). The compressor durability device is shown in Figure 5 and the results are shown in Table 4. In a rotary compressor using R134a, we can avoid seizure and abrasion best by selecting high quality materials for the sliding vane. However, we can't avoid clogging of the capillary tube. For a swing compressor in which hard lubrication is eliminated, there is no lubrication problem for all refrigerants and the capillary tube does not clog. We confirmed that lubrication improves by changing to the swing structure.

4.2.2 Capillary Clogging Test at The Refrigerator System

We evaluated the clogged capillary tube in a refrigerator system of 1 horsepower (see Figure 6). In a system using a rotary compressor, capillary clogging becomes worse over time. In a system using a swing compressor, capillary tubes do not clog as much according to our compressor durability test.

5. Conclusions

The calculations and experimental results with regard to the durability and energy performance of swing compressors are described in this paper. Using alternative refrigerants R134a, R32/134a and R410A, we checked the durability and capillary clogging with a compressor durability test and system test. In addition, the total performance of the compressor improved 2～9%, due to adding new technology to decrease leakage.

Changing to the swing structure from the rotary structure and adding new technology can help us handle alternative refrigerants, increase energy performance, and contribute to solving the ozone depletion problem.

6. References

1. Hirano, et al, "The International Symposium on R22 & R502 Alternative Refrigerants 1994."
2. Iizuka, et al, "Proceedings of Japanese Association of Refrigeration 1993 Vol.10 No.3."
3. Sumida, et al, "Proceedings of 1993 Japanese Association of Refrigeration Annual Conference."
4. Muraki, et al, "The International Symposium on R22 & R502 Alternative Refrigerants 1994."
5. Mishina, et al, "Proceedings of 1992 Japanese Society of Tribologists."
6. Yamamoto, et al, "Proceedings of the 29th Japanese Joint Conference on Air-conditioning and Refrigeration (1995 Tokyo)."
7. Yamazaki, et al, "Proceedings of 1994 Japanese Society of Tribologists."

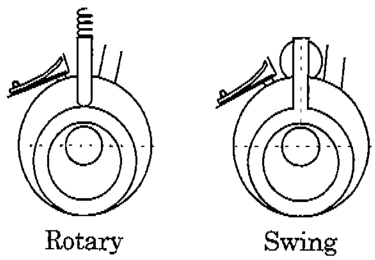


Figure 1. Structure of compressors.

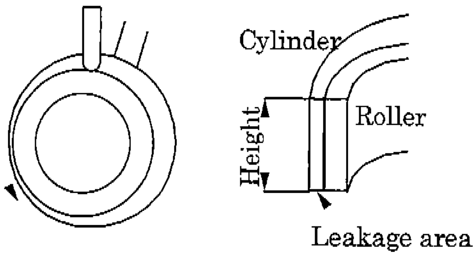
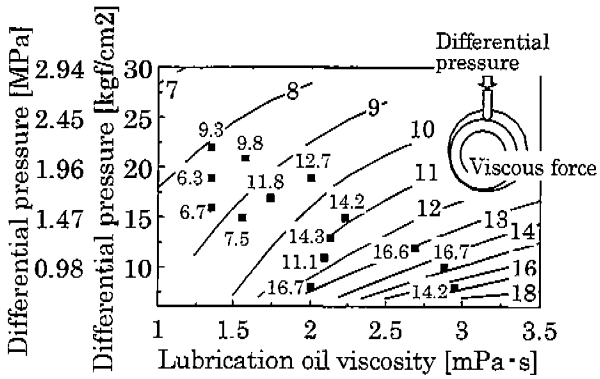


Figure 3. Leakage area between roller and cylinder.



Numbers in the Figure :
Roller rotation ratio per crank rotation.
The contour lines : Results of calculation.
Black points : Results of test.
Refrigerant : R22
Lubrication oil : SUNISO4GS

Figure 2. Roller rotation of rotary compressor.

Table 1. Comparison of mechanical loss in swing and rotary compressors.

Lubrication parts	Swing compressor	Rotary compressor
Main/sub bearing	24.1%	24.0%
Crank-pin bearing	34.5%	31.7%
Vane and roller	- - -	12.5%
Vane side	24.0%	26.5%
Outside of swing bush	6.6%	- - -
Crank thrust	6.0%	5.3%
Total of loss	95.3%	100%
Comparison of the same design and same class of compressor(3/4 horsepower).		

Table 2. Comparison of leakage ratio and decrease of leakage area.

		Leakage ratio
Improved type	12.8cc,Height10mm×2	69%
Old type	13.2cc,Height15mm×2	100%

Table 3. Comparison of the leakage ratio and change in curvature of the leakage channel.

		Leakage ratio
Improved type	φ 60 / φ 54	82%
Old type	φ 44 / φ 36	100%
Refrigerator : R22 Lubrication oil : SUNISO4GS Condition of high pressure side : 22kgf/cm2gage,90℃ Condition of low pressure side : 5kgf/cm2gage,20℃		

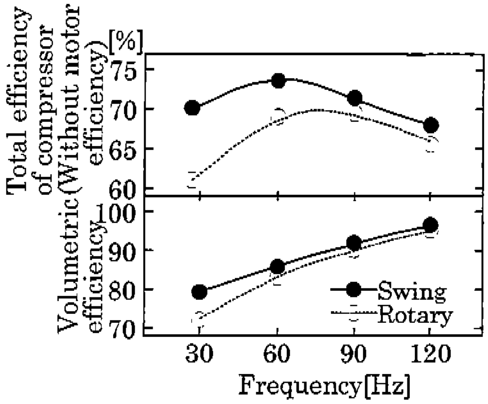


Figure 4. Efficiency of variable speed compressor.

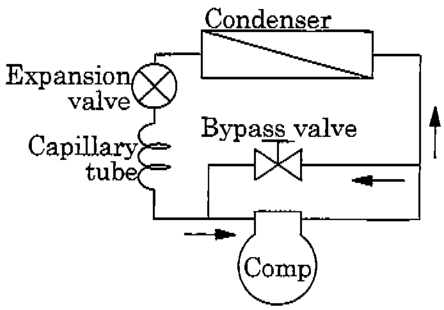
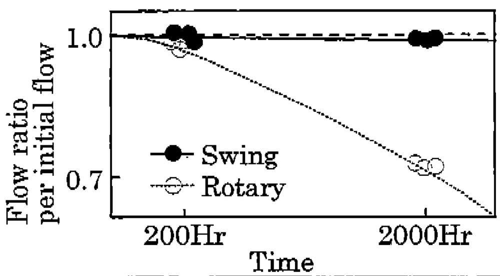


Figure 5. The Compressor durability device.

Table 4. Total results of the compressor durability test.

	R134a		R407C	R410A
	Swing compressor	Rotary compressor	Swing compressor	
Durability	○	○	○	○
Capillary clogging	○	△	○	○
Retrogradation of oil	○	△	○	○

Operation conditions :
Evaporation and condensation temperature are constant.
Operation speed is constant.
Temperature of the discharge gas is 130℃.
Operation time is 200hours.
Lubrication oil ; Ester oil (Adding the antioxidant and the extreme pressure agent, acid catcher agent)
※Rotary compressor using nitriding vane.



Test condition :
Continuous operation on the overload.
Refrigerator : R134a
Lubrication oil : Ester oil

Figure 6. Capillary clogging test on the variable speed heat-pump air conditioner. (1 horsepower)