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Development of Scroll Compressor for 16HP VRF System

Fumikazu Nagaoka
Mitsubishi Electric Corporation, Japan, nagaoka.fumikazu@cj.mitsubishielectric.co.jp

Masashi Myogahara
Mitsubishi Electric Corporation, Japan, Myogahara.Masashi@ak.MitsubishiElectric.co.jp

Taro Kato
Mitsubishi Electric Corporation, Japan, Kato.Taro@db.MitsubishiElectric.co.jp

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Fumikazu Nagaoka, Masashi Myogahara, Taro Kato
Mitsubishi Electric Corporation Shizuoka Works
3-18-1, Oshika, Suruga-ku, Shizuoka-City, Japan
Phone: 81-54-287-3112, Postcode: 422-8528
E-mail: Nagaoka.Fumikazu@cj.MitsubishiElectric.co.jp
E-mail: Myogahara.Masashi@ak.MitsubishiElectric.co.jp
E-mail: Kato.Taro@db.MitsubishiElectric.co.jp

ABSTRACT

Usage of multiple compressors is applied for general VRF system at more than 12HP capacity because it is difficult to keep capacity and performance by usage of one compressor for such large capacity system. But usage of multiple compressors has problem of controlling cost and keeping oil level in each compressor. In order to operate by single compressor up to 16HP VRF, the new scroll compressor which increased approximately 50% displacement was developed and it achieved oil circulation reduction in refrigerant circuit, keeping enough oil level in the compressor, and advanced reliability in low pressure difference operation and low viscosity lubrication operation.

1. INTRODUCTION

It is important to keep oil level in a compressor because VRF system has large refrigerant circuit. Analysis of oil and refrigerant flow in the compressor was applied, and structure of preventing oil agitation was introduced to reduce oil circulation in refrigerant circuit and keep oil level.

The compressor for VRF system is requested to operate in a wide running range from low speed to high speed and from low load to high load. Even in lower pressure difference operation, this new compressor which uses pressure difference oil supply system can supply enough oil for lubrication by new structure of oil supply. And analysis of lubrication between the shaft and the bearing was applied, and new optimal shaft shape can keep reliability against high load at large capacity. This paper introduces these new system and structure to keep reliability for capacity increased compressor.

2. Method of Keeping Oil Level

2-1. Gas Flow in the Compressor

Figure 1 shows the cross-section view of the scroll compressor. Mechanical section and stator are fixed inside a sealed shell, and rotor is fixed with shaft to keep clearance against stator. Refrigerant gas flows through the suction pipe. The gas gets compressed at the compression chamber and flows out from discharge port. The high pressure gas and oil mist flow to bottom of shell. In this process, the gas and the oil mist are separated. The separated gas flows through holes inside a rotor and flows out of the shell.

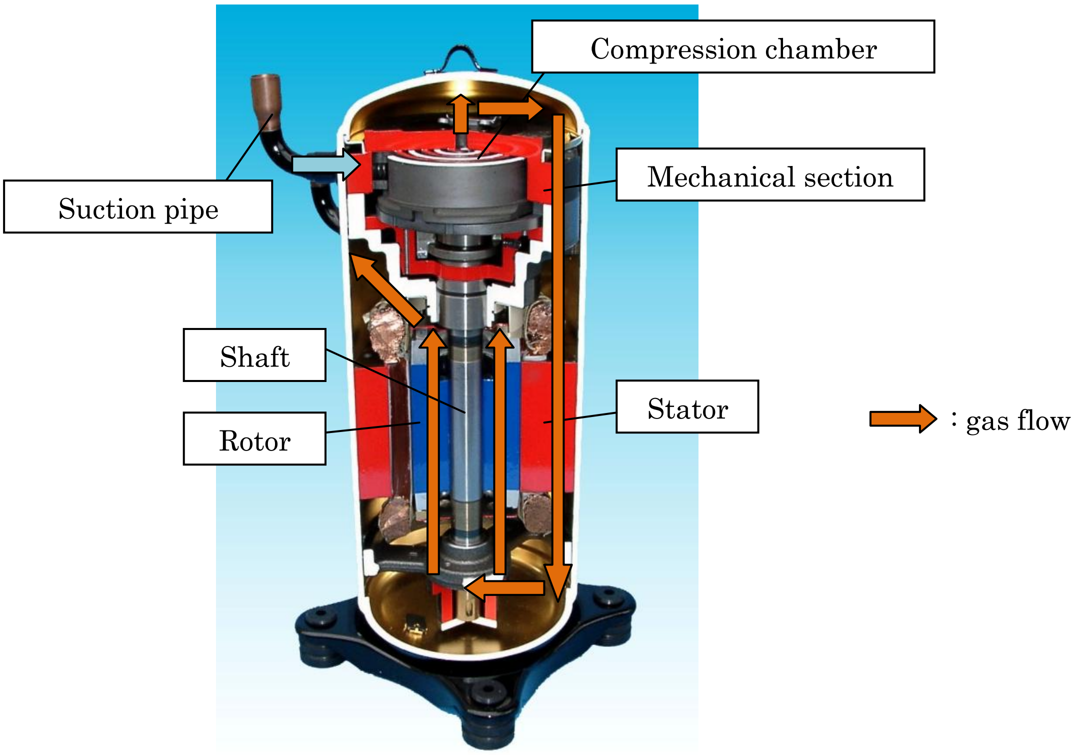

Fig 1. Cross section of Compressor

2-2. Oil Keeping Structure

It is important to keep oil level in a compressor because VRF system has large refrigerant circuit. Figure 2 shows structure under rotor. It is difficult for conventional compressor to keep enough oil level because balance weight located under rotor agitates oil in bottom of the shell. Therefore, new structure CUP to cover the balance weight and prevent oil agitation was introduced to reduce oil circulation in refrigerant circuit and keep oil level.

At first, simulation of the gas and the oil flow in the compressor was evaluated. Figure 3 shows simulation result of flow velocity from lower side to upper side in the rotor hole.. Flow velocity at bottom of the shell for new structure decreases compared with conventional structure. From this result, CUP which covers the balance weight can prevent oil agitation by balance weight, and oil amount carried from bottom of the shell can be reduced by decreasing flow velocity in rotor hole.

Next, oil circulation ratio in refrigerant circuit was measured. Figure 4.1 shows measurement result at compressor starting, and Figure 4.2 shows measurement result at compressor rated operating condition. Effect of new structure for reducing oil circulation was confirmed with actual compressor operation.

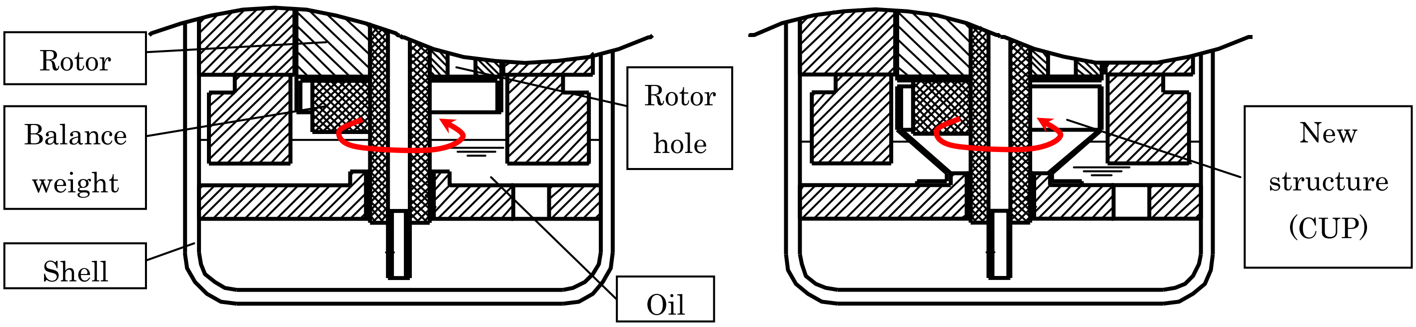

Fig. 2.1. Conventional structure

Fig.2.2. New structure

Fig 2. Structure under rotor

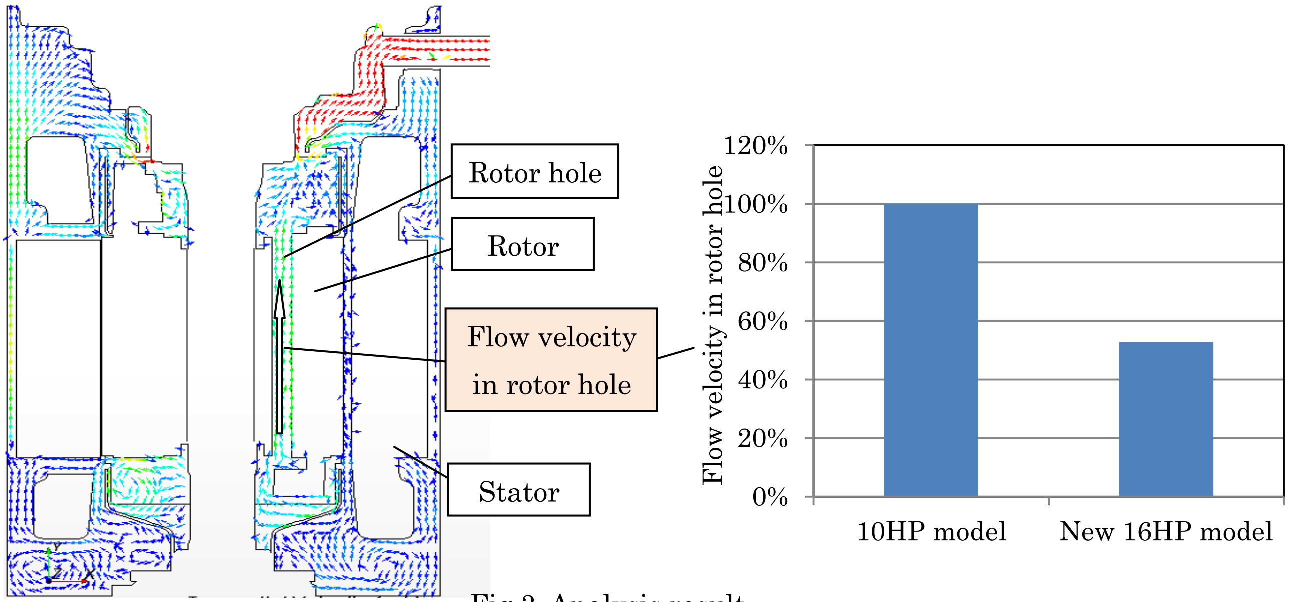

Fig 3. Analysis result

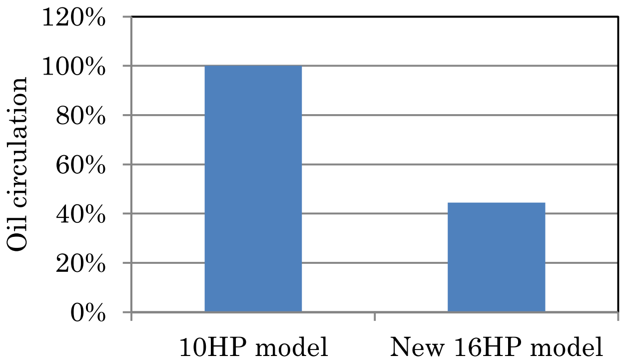

Fig 4.1. At the compressor starting

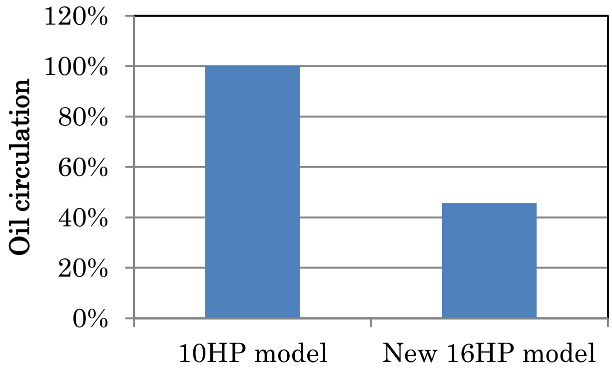

Fig 4.1. At rated operating

Fig 4. Oil circulation with actual compressor

3. Method of shaft load durability improvement

In case of compressor capacity increase, load on bearing by gas compression will be increased, and there is possibility of bearing scuff by lower oil viscosity in soaking start or liquid flood back operation. To prevent the failure, countermeasure to keep durability of lubrication between the shaft and the bearing is required.

Therefore, "Nano-grinding" machining technology is introduced to improve durability of lubrication. It can achieve smooth shaft surface shown in Figure 5. Load absorbing area of the shaft surface is increased by improvement of surface roughness and load limitation against bearing scuff is improved by 50% compared with conventional shaft shown in Figure 6.

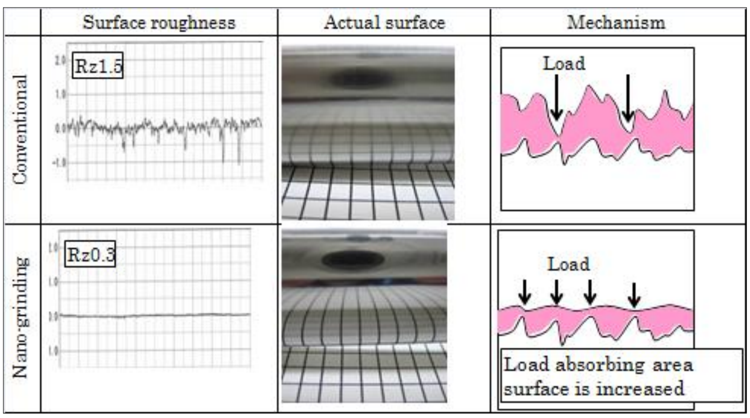

Fig 5. "Nano-grinding" machining

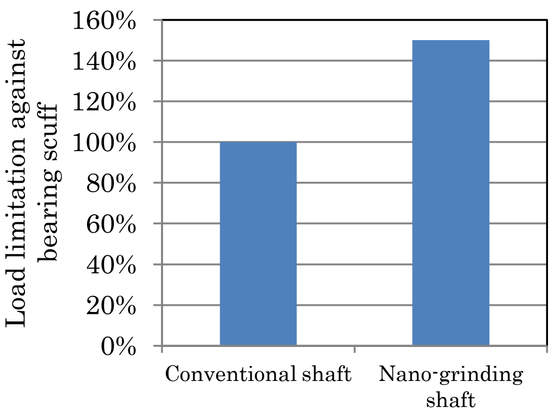

Fig 6. Load limitation

4.Method of Oil Supply in Low Pressure Difference

4-1. New Oil Supply Structure

In case of part load operation, operating pressure difference tends to decrease. It affects compressor oil supply by pressure difference. For improvement of oil supply in lower pressure difference operation, new oil supply structure was introduced.

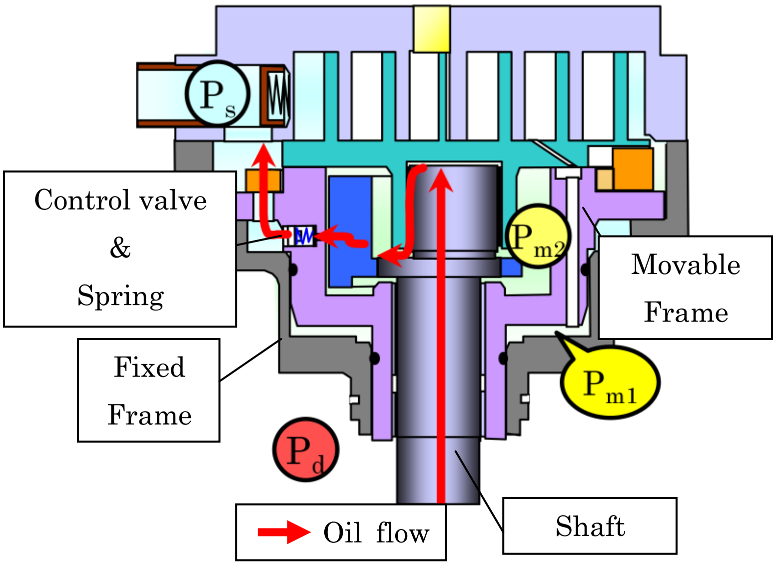

Fig 11. Compliant structure

Figure 11 shows compliant structure in the scroll compressor. Movable Frame which can move to the vertical direction along the shaft is set inside Fixed Frame. Two intermediate pressures are constructed in this structure. One of intermediate pressure is inside of "Movable Frame back pressure chamber" between Movable Frame and Fixed Frame. Another one is inside of "Orbiting Scroll back pressure chamber" between Orbiting Scroll and Movable Frame. Leakage loss and mechanical loss at thrust bearing will be minimized by these two intermediate pressures.

Movable Frame back pressure is controlled by pressure inside compression chamber as mentioned in equation (1).

$$P_{m1} = P_s * \beta \quad (\beta : \text{Compression ratio inside compression chamber}) \qquad (1)$$

Orbiting Scroll back pressure is controlled by Control Valve opening. Control Valve is forced by spring and it will open when pressure inside Orbiting Scroll back pressure chamber become equal to the sum of force by suction pressure(P_s) and spring force as mentioned in equation (2).

$$P_{m2} = P_s + \alpha \quad (\alpha : \text{Spring force}) \qquad (2)$$

Oil is supplied from shell bottom through shaft inside hole by pressure difference between discharge pressure (P_d) and Orbiting Scroll back pressure. Pressure difference ΔP is mentioned in equation (3).

$$\Delta P = P_d - P_{m2} \qquad (3)$$

Oil can be supplied at pressure difference $\Delta P > 0$ even if rotational speed is low. But if discharge pressure is lower than P_{m2} like part load operation, oil cannot be supplied.

Therefore, new oil supply structure is introduced to supply enough oil at low pressure difference as shown in Figure 12. Intermittent opening hole is added to Orbiting Scroll. Refrigerant gas inside Orbiting Scroll back pressure chamber flows through this hole to suction area. ΔP will be controlled by new oil supply structure as mentioned in equation (4.1), (4.2).

$$\Delta P = P_d - P_{m2}' \qquad (4.1)$$

$$P_{m2}' = P_s + \alpha - \gamma \qquad (4.2)$$

New oil supply structure can keep ΔP more than "0" at all operating condition because Orbiting Scroll back pressure is reduced by intermittent opening hole (γ is controlled by intermittent opening hole position and the open range.) And opening range of this hole is adjusted to prevent mechanical loss increase at not low pressure difference condition.

Effect of Orbiting Scroll back pressure chamber control change is presented in Figure13. New structure can supply oil in the condition of "Pd-Ps< α", and it can achieve lubrication reliability in lower pressure difference operation.

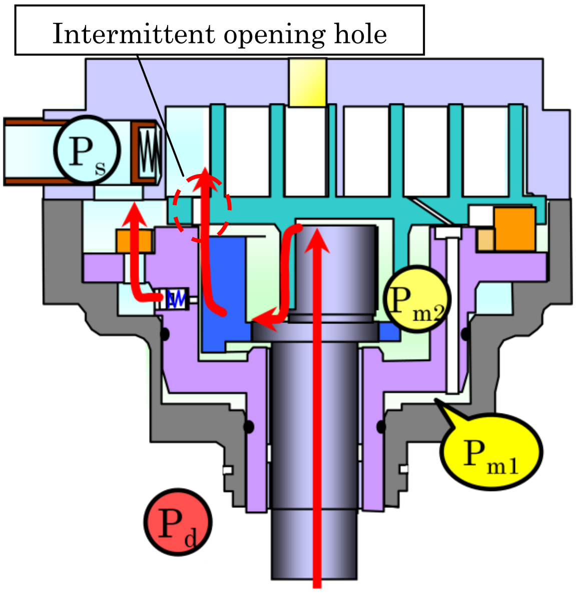

Fig 12. New oil supply structure

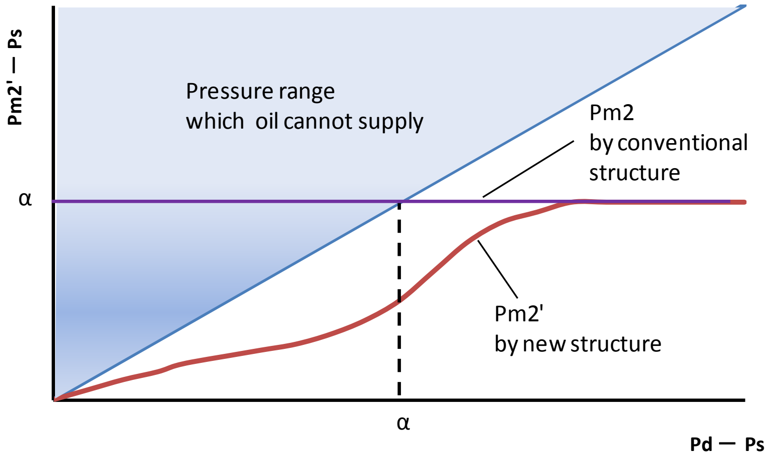

Fig 13. Pressure difference and oil supply

5.Conclusion

To develop large capacity scroll compressor for 16HP VRF, anxious points against reliability was solved as below countermeasure.

1) By simulation of the gas and the oil flow in the compressor, optimal structure for keeping oil level in the compressor was designed and this structure can keep oil at actual operation.
2) By introduction of "Nano-grinding" machining technology, load limitation against bearing scuff is improved by 50% and durability of lubrication was kept.
3) By new oil supply structure, it could achieve lubrication reliability in lower pressure difference operation.