Small and High-Efficiency 3-HP DC Twin Rotary Compressor

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Mitsubishi Heavy Industries Ltd. (MHI) previously developed a small and highly efficient DC twin rotary compressor for R410A refrigerant, for use in 4 to 6-HP air conditioners for commercial use. This paper describes the company's new 3-HP DC twin rotary compressor, which was designed to be even smaller and more efficient.

1. Introduction

MHI is continuously improving the efficiency of compressors for air conditioners to save energy and reduce annual energy consumption.[1] In recent years, there is increasing demand for smaller outdoor units of the air conditioning system to save resources and allow for easier installation. In response to this demand, one technology trend within the industry involves expanding the capacity of compressors that are smaller than conventional ones. MHI recently developed a 3-HP DC twin rotary compressor for R410A refrigerant; this compressor is smaller and more efficient than competing products. This paper provides an overview of this new compressor.

2. Features of the MHI Twin Rotary Compressor

2.1 Smaller size

Figure 1 compares the external dimensions of MHI's newly developed 3-HP twin rotary compressor with competitors. MHI's new compressor has an external diameter smaller than the competitors' equivalent DC twin rotary compressor, resulting in a smaller size and lighter weight, which enhances ease of installation in the outdoor unit and saves resources.

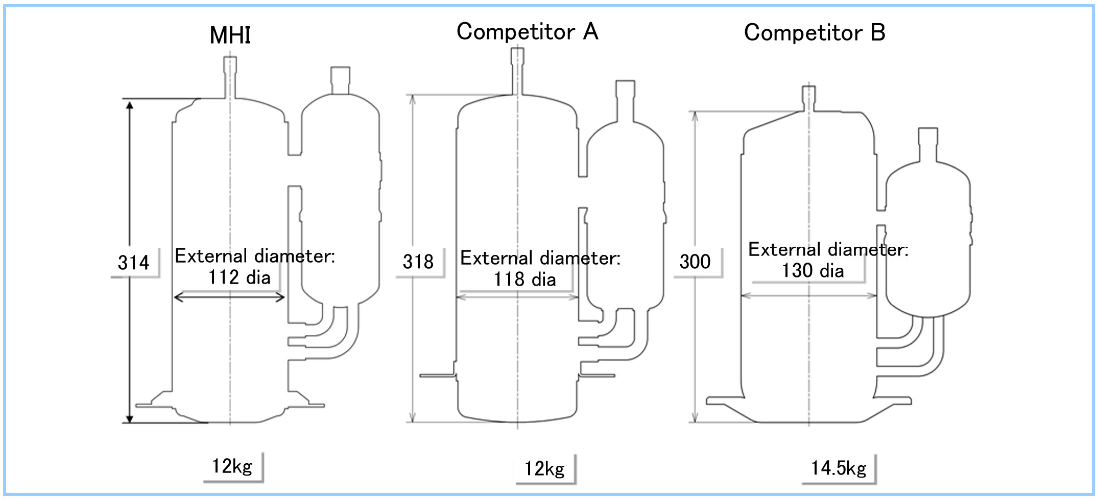

Figure 1 Comparison of external dimensions

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2.2 Increased efficiency

Figure 2 shows the internal structure of MHI's newly developed 3-HP twin rotary compressor.

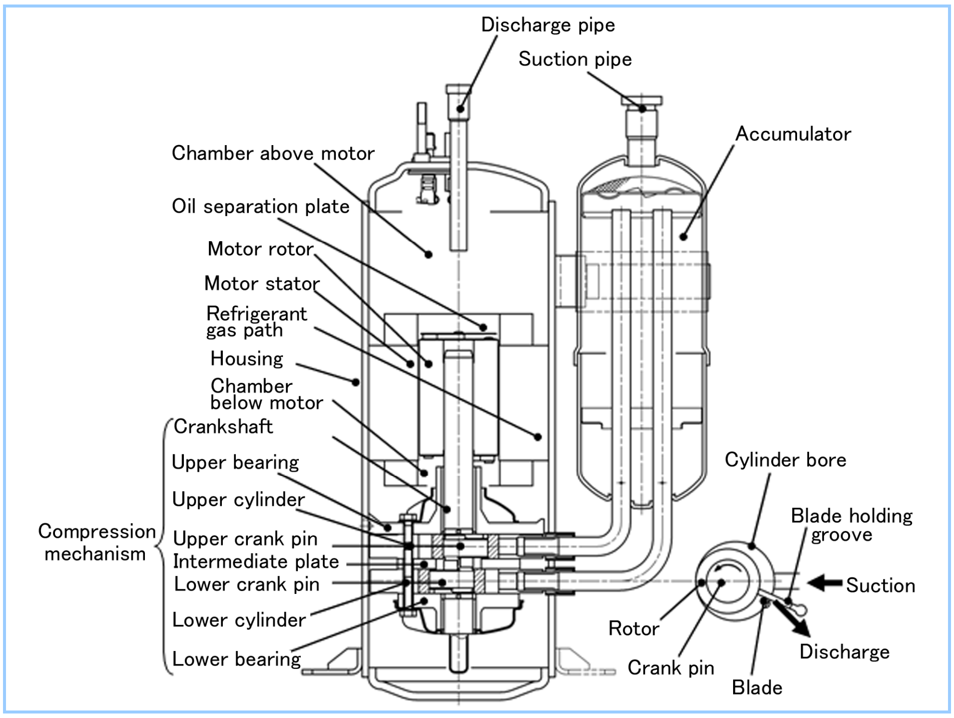

Figure 2 Internal structure of the twin rotary compressor

With regard to the compression mechanism, the crankshaft diameter has been reduced from 20 dia. in previous 3-HP compressors to 16 dia., resulting in less mechanical loss at the bearings. The upper and lower cylinder widths have been reduced by approximately half overall, as compared to previous single rotary compressors, and the bores have been expanded, reducing leakage loss and increasing capacity.

In previous MHI rotary compressors, the compression mechanism was fixed to the compressor housing by spot-welding the upper cylinder. Reduction of the width and increase of the bore of this cylinder meant it would lose its rigidity, which could result in thermal deformation due to welding, leading to negative effects with regard to compressor efficiency and reliability. Therefore, MHI has adopted a new structure in which the outer circumference of the upper bearing is welded onto the housing. **Figure 3** shows an example FEM analysis of cylinder deformation due to welding. Deformations of the blade holding groove and the cylinder bore were observed in the previous structure in which the cylinder is welded, but no cylinder deformation appears in the new structure in which the upper bearing is welded. Therefore, the new process eliminates the possibility of reduced efficiency and reliability.

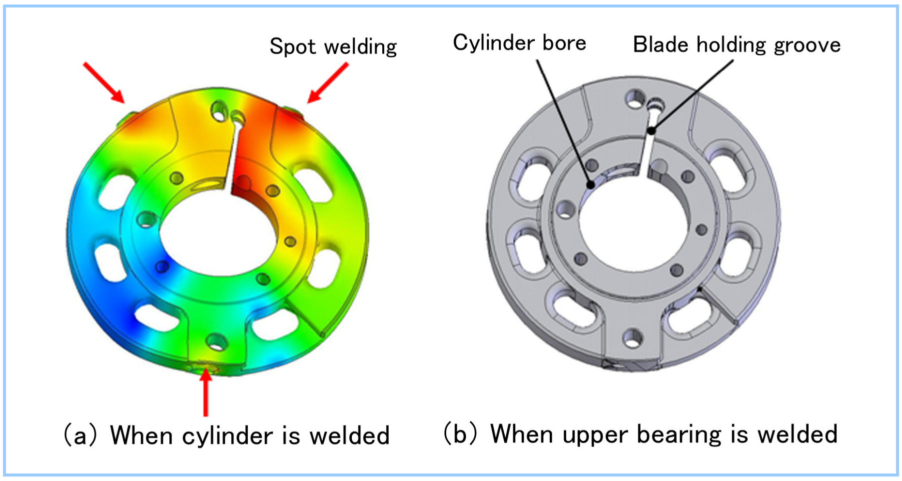

Figure 3 Example FEM analysis of the cylinder

With regard to the motor, which is strongly related to compressor efficiency, MHI has adopted a concentrated winding DC motor with a rare earth permanent magnet, which is more powerful and efficient than the original distributed winding DC motor with a rare earth permanent magnet. To improve the Annual Performance Factor (APF), a detailed magnetic field analysis was executed to facilitate the design of a more efficient low speed section in particular; this improved efficiency by approximately 4%, as compared to the original distributed winding DC motor with equivalent power.

Figure 4 compares efficiency between a concentrated winding motor and a distributed winding motor.

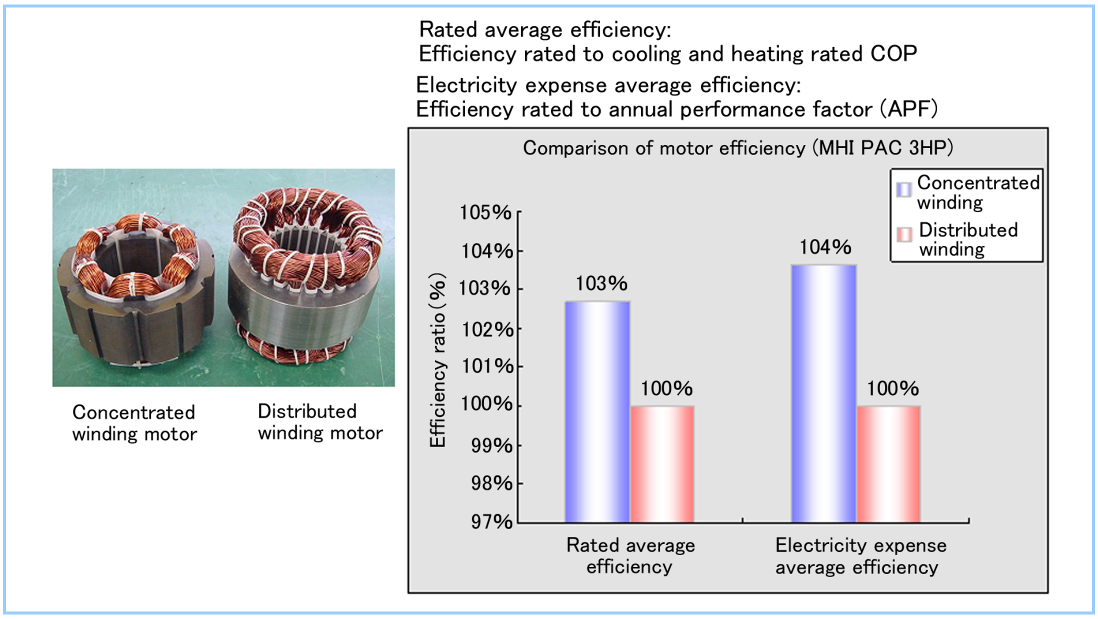

Figure 4 Comparison of motor efficiency

Through these technologies, the new compressor is 4% more efficient than the MHI twin rotary compressor equipped with a distributed winding motor, as shown in **Figure 5**, enabling greater efficiency than those of competitors.

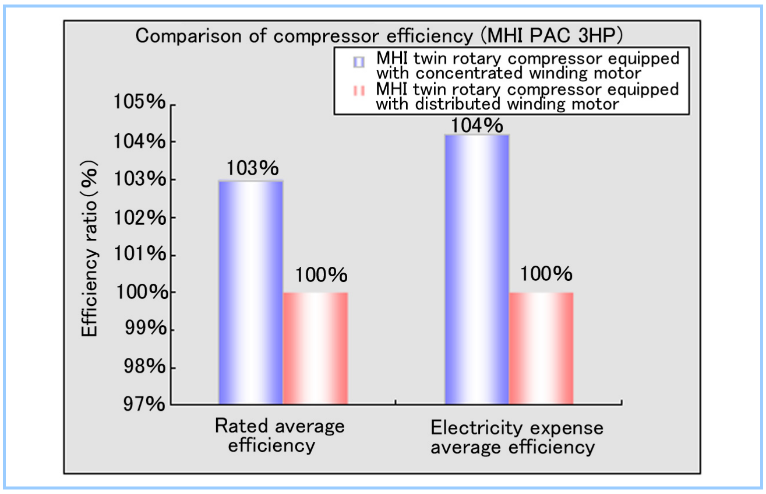

Figure 5 Comparison of compressor efficiency

2.3 Improved reliability

Although a reduced crankshaft diameter can effectively reduce mechanical loss, it is also more likely to cause abnormal wear, such as abnormal bearing wear and seizure, as a result of increased shaft deformation. As a countermeasure, MHI has adopted a highly rigid shaft structure (**Figure 6**), similar to previously-developed 6-HP compressors. In particular, the cross-section of the intermediate shaft between upper and lower crank pin is shaped such that it minimizes deformation in the direction in which the maximum reactive force of refrigerant gas compression acts.

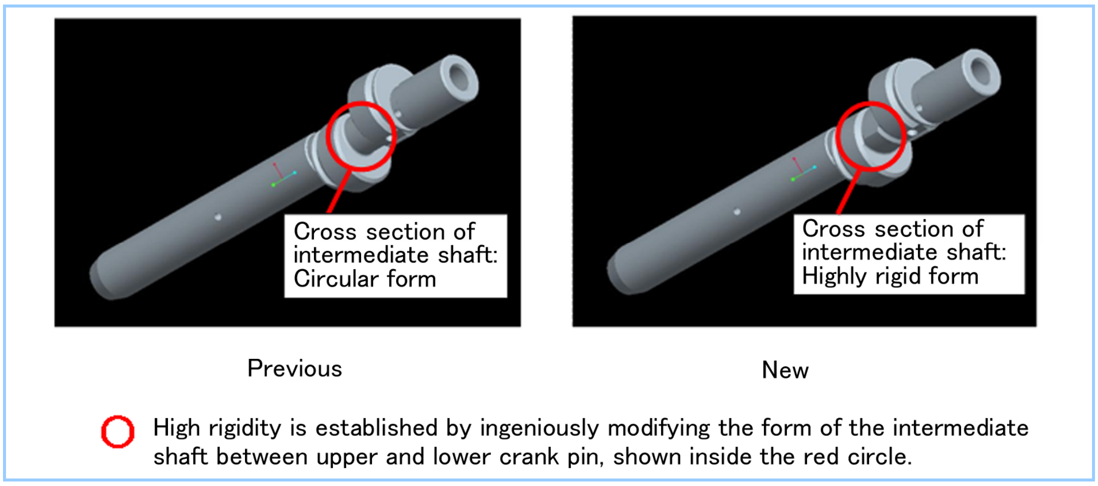

Figure 6 Highly rigid crankshaft

Refrigerant oil plays an important role by lubricating sliding parts and sealing the compression mechanism. It circulates in the refrigeration cycle together with a certain ratio of refrigerant, which is an operating fluid. The weight percentage of the oil circulating in the cycle against the sum of the oil and refrigerant is called the oil circulation ratio, which increases in proportion to the refrigerant mass flow rate and the compressor revolution speed. If refrigerant oil flows out to the refrigeration cycle, it hampers heat transfer in the heat exchanger, reducing cycle efficiency and reduces the retained oil level inside the compressor, thereby decreasing its ability to lubricate the sliding parts of the compressor.

MHI has therefore adopted a structure in which the oil is separated in the chamber above the motor to control increases in the oil circulation rate. The mixture of refrigerant and oil mist, which moves up the refrigerant gas path connecting the chambers above and below the motor, flows out of the compressor through the bottom of the discharge pipe located at the upper center of the compressor. The oil separation plate (**Figure 7**) is installed on the upper part of the motor rotor, closest to the bottom of the discharge pipe. **Table 1** shows the effectiveness of the oil separation plate: it reduces the maximum oil circulation ratio to less than half that without an oil separation plate.

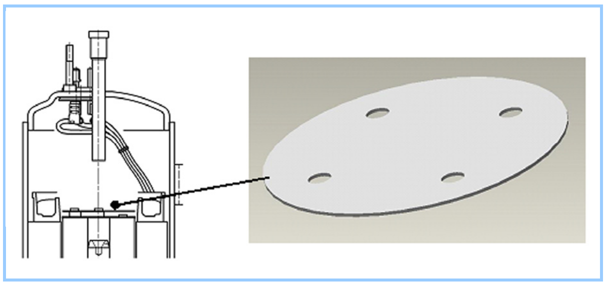

Figure 7 Structure of oil separation plate

Table 1 Effectiveness of the oil separation plate on oil circulation ratio

	Rate (-)
No oil separation plate	1.00
Equipped with oil separation plate	0.46

@120 rps maximum cooling condition

3. Conclusion

The 3-HP DC twin rotary compressor for R410A refrigerant, developed by MHI, has successfully achieved the smallest size and highest efficiency in its class due to combination of the existing MHI technologies (from the development of the 6-HP compressor) and new technologies.

This newly-developed compressor is scheduled to be mass-produced by MHI's foreign related company.

Reference

1. Fujita et al., The Smallest and Most Lightweight High-Efficiency 6-HP DC Twin Rotary Compressor in the Industry, Mitsubishi Heavy Industries, Ltd. Technical Review Vol. 45 No. 2 (2008) pp.19-22