The Smallest and Most Lightweight High-Efficiency 6-HP DC Twin Rotary Compressor in the Industry

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Consistent with the current industrial market demands for increased capacity of small compressors, Mitsubishi Heavy Industries, Ltd. (MHI) has developed the smallest and most lightweight DC twin rotary compressor for R410A refrigerant with a maximum capacity of 6 HP. The company approached this design challenge by defining various capacity increase limitations utilizing its original technologies and then successfully reducing the crankshaft deflection under heavy-load operating conditions. At the same time, MHI has succeeded in producing a highly reliable and efficient compressor, which is the smallest and most lightweight unit in the industry, by maintaining the oil circulation ratio during operation and increasing the refrigerant circulation volume to levels comparable with those found in conventional-sized compressors.

1. Introduction

More efficient compressors are required to reduce their annual energy consumption, resulting in energy savings. There is market demand for increased capacity of compressors smaller than conventional ones with size reduction of the outdoor unit to save on resources and for ease of installation. MHI has developed the smallest and most lightweight high-efficiency DC twin rotary compressor for R410A refrigerant that is a maximum capacity of 6 HP.

This paper described the technology, which satisfies mutually contradictory requirements that include increased capacity, increased reliability, and improved efficiency for small compressors.

2. Outline of the twin rotary compressor

2.1 External appearance

Figure 1 shows the external dimensions of our new 6-HP twin rotary compressor. This compressor provides 39% space savings and 56% weight reduction as compared to our competitors' 6-HP constant-speed scroll compressors, and 11% space savings and 22% weight reduction as compared to our competitors' 6-HP DC twin rotary compressors. These achievements contribute toward improving the compressor's mountability on the outdoor unit while reducing the overall weight.

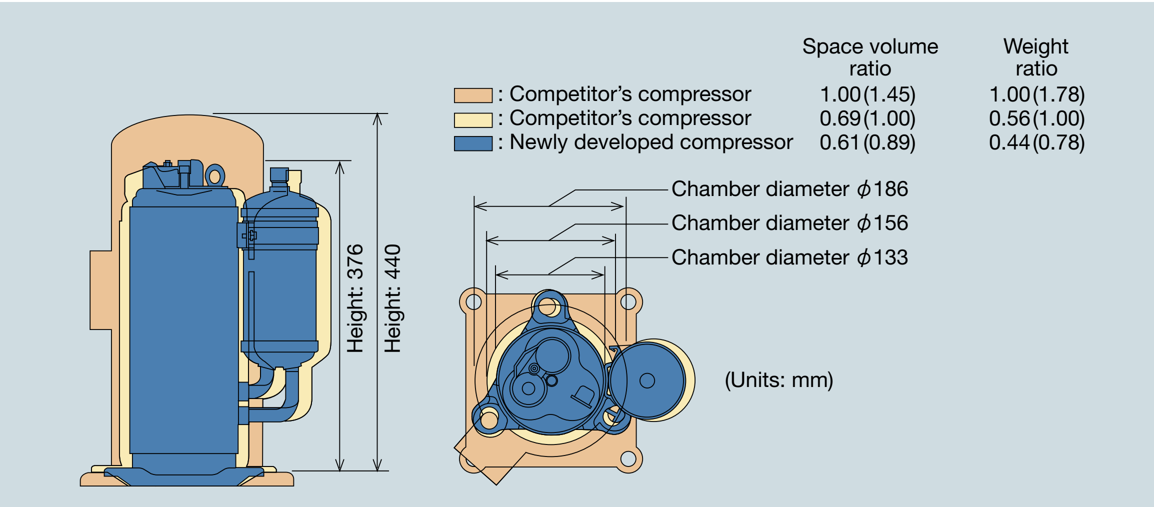

Fig. 1 Comparison of external dimensions and weight

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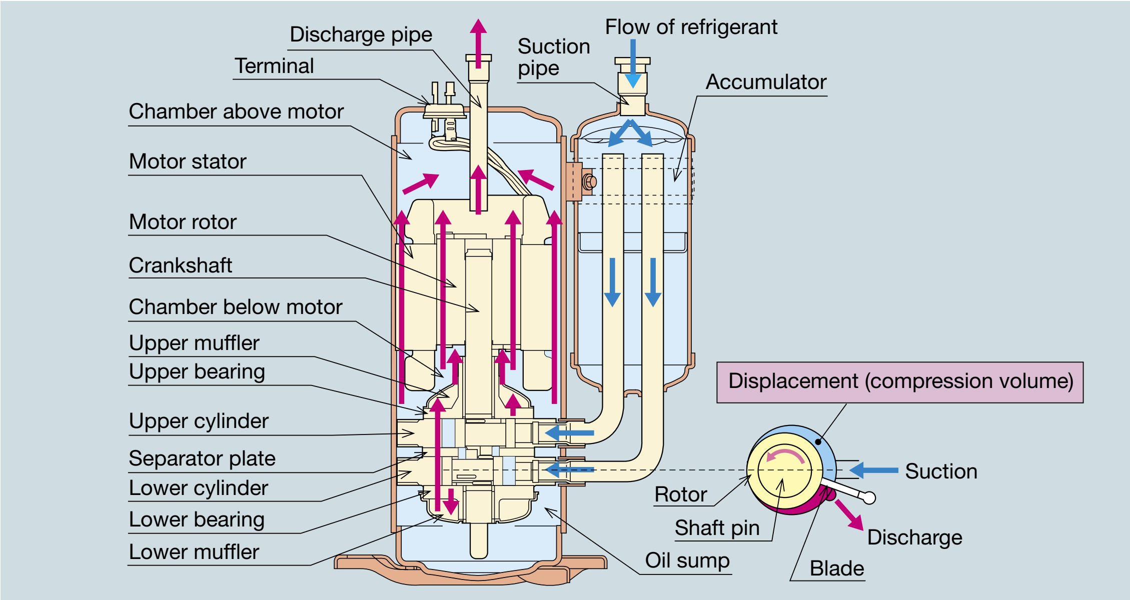


Fig. 2 Cross-sectional view of the twin rotary compressor

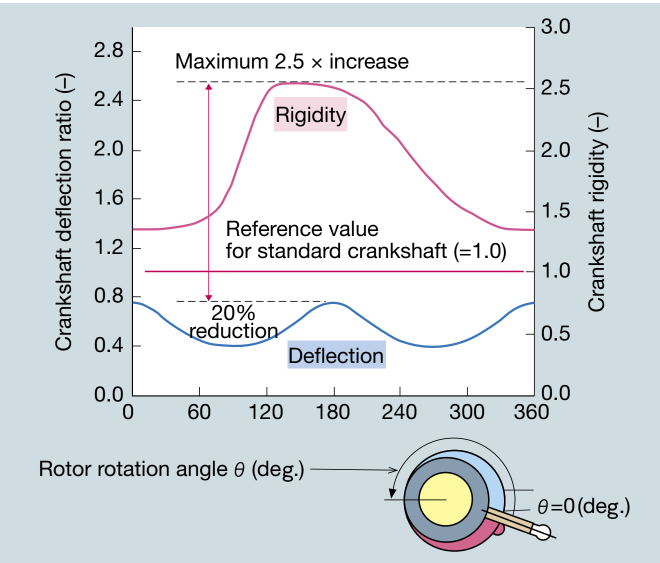


Fig. 3 Crankshaft rigidity and deflection

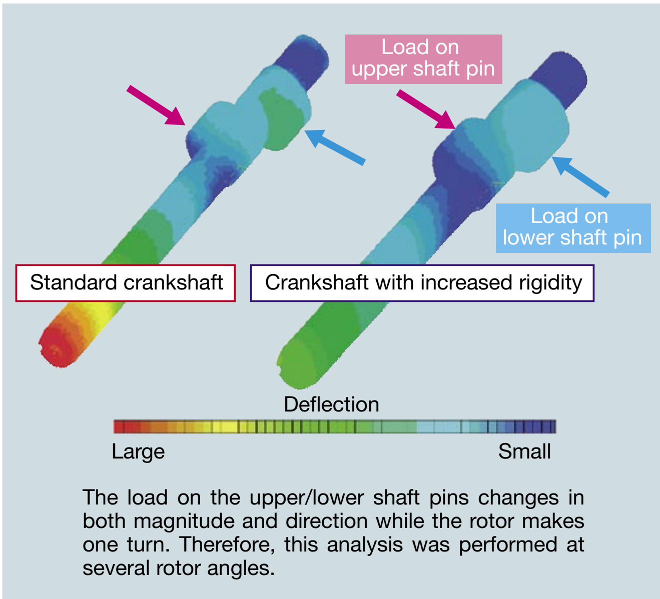


Fig. 4 Finite element analysis of the crankshaft
The data shown in Fig. 3 were validated by detailed finite element analysis.

2.2 Internal structure

Figure 2 shows the internal structure of the twin rotary compressor. The compressor capacity is proportional to the displacement (compression volume). The size of the compressor cylinder is determined by the diameters of the cylinder and motor, and is also influenced by the crankshaft diameter. Therefore, to increase the capacity of small compressors, it is necessary to increase the rotor displacement without changing these diameters.

3. Size reduction

3.1 Bearing reliability

The increase in displacement increases the load applied to the crankshaft. There is a risk of abnormal bearing wear or seizure due to the increase in local contact pressure generated by any crankshaft deflection. Therefore, we adopted a configuration that helps to effectively increase the crankshaft rigidity in the load direction without increasing its diameter to reduce crankshaft deflection during high-load operation. **Figure 3** shows an analysis of the crankshaft deflection and rigidity during one turn of the rotor. Increases in local contact pressure caused by the increased displacement were prevented when deflection of the crankshaft with increased rigidity was reduced by more than 20% as compared to a conventional crankshaft. Based on this result, we performed detailed finite element analysis (**Fig. 4**) and conducted a confirmation test using actual units to verify their reliability.

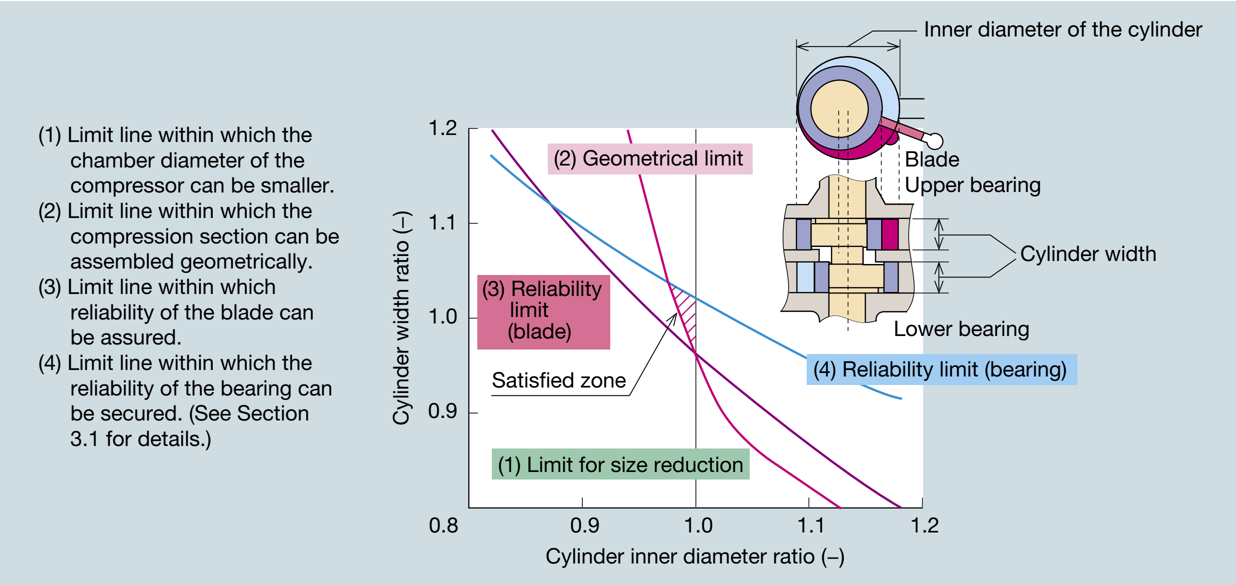


Fig. 5 Zone satisfied by the rotary compressor specifications

An appropriate combination of cylinder inner diameter and width as the main specifications of a rotary compressor must fall within an area surrounded by the limit lines (the satisfied zone) shown in **Fig. 5**. MHI was able to increase the capacity of its small compressors by relaxing the reliability limit for the bearing by effectively increasing the crankshaft rigidity, and by clearly defining the values for other limits through implementation analyses and confirmation tests using actual units.

3.2 Reduction of oil circulation ratio

Refrigerant oil in the bottom section of the compressor serves to lubricate the sliding parts and to seal the leak clearances of the compression section. As the oil circulation ratio increases, the volume of the refrigerant oil taken out of the compressor together with the refrigerant gas also increases. In particular, when the capacity of a small compressor increases, the oil separation efficiency inside the compressor decreases as the refrigerant flow rate increases with the capacity of the compressor (volumes of the motor adopting/receiving chambers: Fig. 2), thus increasing the oil circulation ratio. A reduction in the volume of oil inside the compressor not only adversely affects the reliability of the compressor itself, but also inhibits heat transfer in the heat exchanger, thus reducing the efficiency of the system. To address this problem, MHI optimized the configuration of the inner/outer circumference passages of the motor. These serve as refrigerant gas passages connecting the motor adopting chamber and the motor receiving chamber. As a result, the oil circulation ratio for MHI's compressor is much less than those of our competitors' 4 to 5-HP compressors, which have almost the same chamber diameters, as shown in **Fig. 6**. Our oil circulation ratio is approximately the same as those of our competitors' 6 to 8-HP compressors, which have larger chamber diameters.

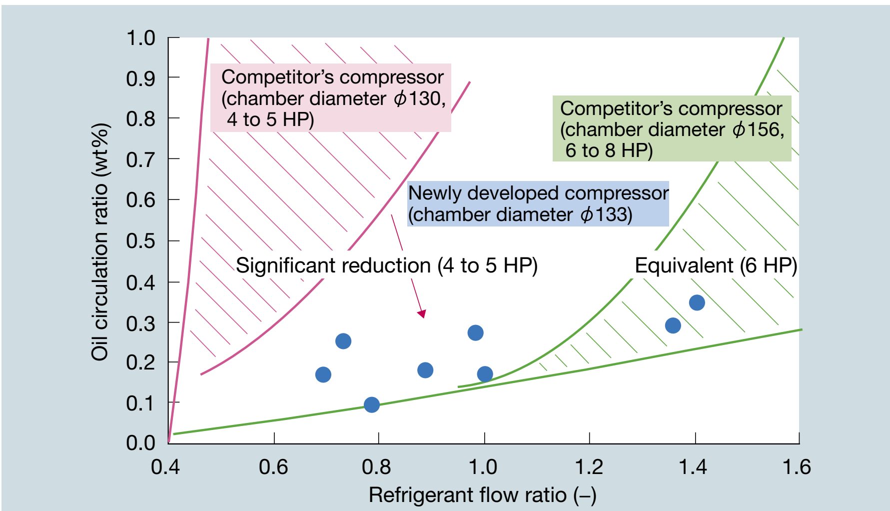
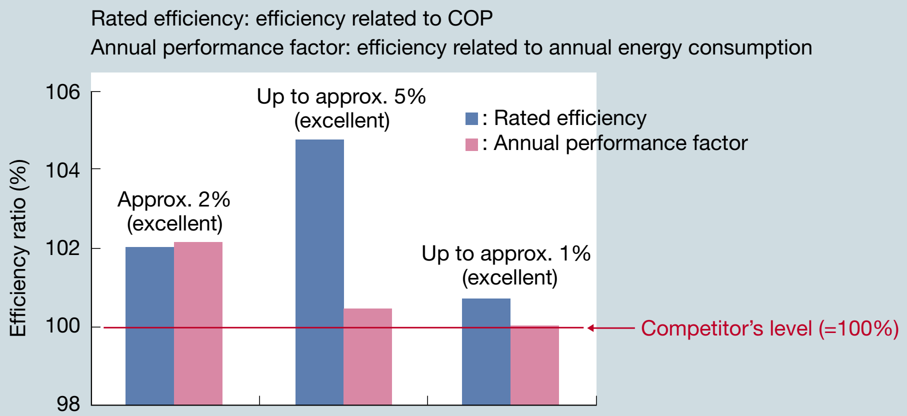


Fig. 6 Comparison of lubricant discharge volume



(Chamber diameter)	4 HP	5 HP	6 HP
Newly developed compressor	133ϕ	133ϕ	133ϕ
Competitor's compressor	130ϕ	130ϕ	156ϕ

Fig. 7 Comparison of compressor efficiency

4. Efficiency improvement technology

Detailed deflection analysis of the crankshaft, as described in Section 3.1, and effective reduction of crankshaft deflection led an optimized leak clearance for the compression section. In addition, by reducing the oil circulation rate, as described in Section 3.2, the sealing performance of leak clearance in the compression section was improved over a wide range of operating conditions. A high level of efficiency over a range of speeds was achieved through use of a highly efficient DC neodymium motor. Thus, the development of a 4- to 6-HP series compressor based on the above technology resulted in a unit that is more efficient than those of our competitors for all HP settings, as shown in **Fig. 7**.

5. Conclusion

The 6-HP DC twin rotary compressor for R410A refrigerant developed by MHI is highly reliable and efficient, and is the smallest and most lightweight unit in the industry. This compressor has already been put into commercial production at Thai Compressor Manufacturing Co., Ltd. (THACOM, **Fig. 8**), which was established in 1989 as a Thai-Japan joint venture company. In addition to supplying compressors for MHI units, THACOM also serves as a key site for marketing compressors as independent units.

Fig. 8 External appearance of THACOM (Chachoengsao, Thailand)

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