An Environmentally Friendly, Highly Efficient, Lightweight Scroll Compressor (QS90) for Car Air Conditioners

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In recent years, global efforts towards conserving energy have accelerated in various fields, pushed by rising concern about global environment protection. Mitsubishi Heavy Industries, Ltd. (MHI) has featured high-efficiency scroll compressors in a number of its refrigerating and air-conditioning products, contributing to energy conservation. For car air conditioners, weight is an important factor in addition to efficiency. Therefore, with the introduction of the original new technology (3D scroll, direct oil return system), MHI developed a compressor with reduced energy loss, which was realized through both improved efficiency and weight reduction.

1. Introduction

In recent years, public awareness of environmental protection on a global scale has increased and efforts to combat global warming have accelerated in both the public and private sectors. In addition, the rising prices of crude oil and materials have prompted further energy and resource conservation.

Most current car air conditioners operate on the refrigeration cycle, which requires the combination of a compressor, heat exchanger, and expansion valve. The compressor is driven by the car engine through a belt and pulley and compresses the refrigerant. In this type of air conditioner, the compressor consumes the majority of the power used.

Therefore, to reduce the energy consumption of car air conditioners, it is essential to improve compressor efficiency and thereby contribute directly to a reduction in engine load. In addition, since much energy is required in the production of aluminum, which is the primary raw material for compressors, reducing the weight of compressors is important for both resource and energy conservation.

This paper introduces efficiency improvement and weight reduction technologies for compressors that are essential to the development of environmentally friendly car air conditioners.

2. Efficiency improvement of QS90

2.1 Structure of new scroll (3D scroll[note])

Figure 1 shows a cross-sectional view of the new QS90 scroll compressor for car air conditioners. The scroll compressor consists of a compression unit comprised of a pair of scrolls (a fixed scroll and an orbiting scroll), each composed of end plates and wrapped scroll blades, and a unit that drives the orbiting scroll through the crankshaft. The crankshaft, which is rotated by the engine, moves the orbiting scroll via a belt in an orbital motion using a rotation-motion-prevention mechanism, to compress the refrigerant.

The QS90 compressor adopts a scroll (3D scroll) compressor that was recently developed for the purpose of efficiency improvement. **Figure 2** shows cross-sectional views of conventional and 3D scroll compressors.[1] In the conventional scroll compressor, the wrap height is constant throughout the compression process. Therefore, the refrigerant is compressed in two dimensions from the outer to the inner sides. In the 3D scroll compressor, the outer wrap is higher than the inner one because of the steps in the scroll tips and end plates. Consequently, the 3D scroll can

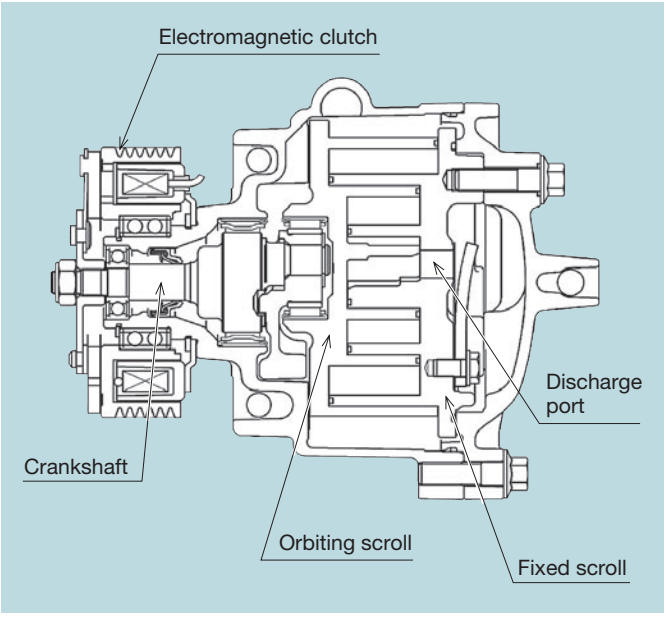

Fig. 1 The newly developed scroll compressor for a car air-conditioner (QS90)

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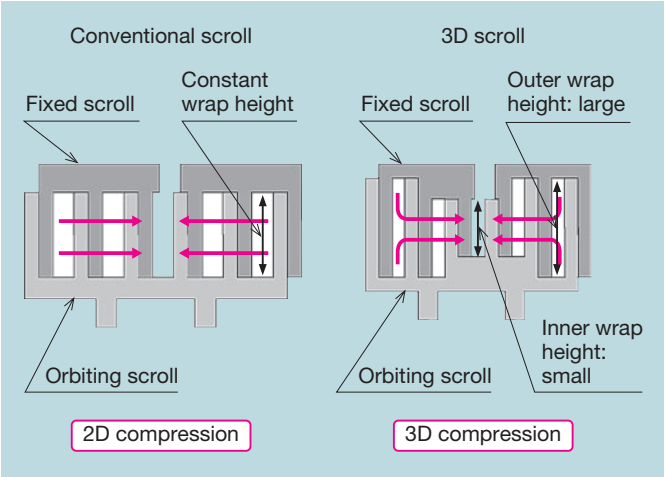

Fig. 2 Cross-sectional view of conventional and 3D scrolls
Introduction of the 3D scroll enables 3D compression.

compress the refrigerant in three dimensions, in the axial dimension as well as the radial directions. The 3D scroll compressor has the following features:

- A high compression ratio is obtained by compressing the refrigerant both radially and axially.
- The strength of the scroll is improved by reducing the height of the inner wrap, which receives a heavy load.
- A large capacity is obtained by increasing the height of the outer wrap without extending the outer diameter of the scroll. Therefore, the 3D scroll is smaller and lighter.

Note: The 3D scroll is a registered trademark of MHI.

2.2 Efficiency improvement with the 3D Scroll

To improve the efficiency of the scroll compressor, the specific parts where power loss occurs were analyzed. **Figure 3** shows the results of the loss analysis of a conventional scroll compressor.[2] It was found that the largest loss was caused by recompression.

One of the features of the 3D scroll compressor is that it can produce a high compression ratio by compressing the refrigerant both radially and axially. This feature reduces the power loss caused by recompression. **Figure 4** shows the results of a bench test of the overall adiabatic compression ratio under two conditions–equivalent to idling and equivalent to running at 40 km/h–for a QS90 compressor and a conventional compressor (MSC90CAS).

When mounted in the same model of vehicle, the QS90 compressor was 7% more efficient than the conventional compressor under conditions equivalent to idling and 13% more efficient under conditions equivalent to running at 40 km/h.

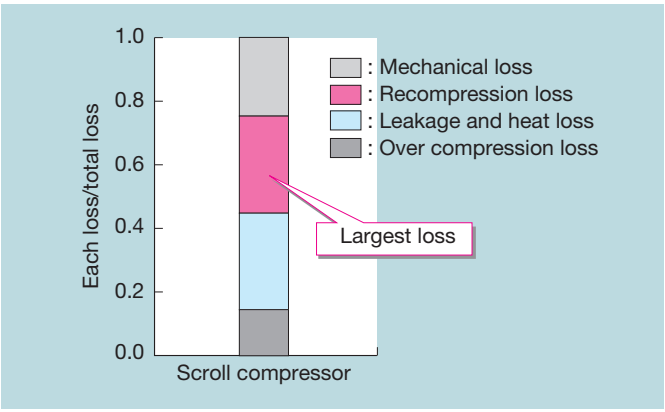

Fig. 3 Power loss analysis of a conventional scroll
Recompression causes the greatest loss.

3. Weight reduction of the QS90

The sliding sections of the compressors in car air conditioners are lubricated by mixing oil with refrigerant and circulating it in the air conditioner. The reliability of lubrication is improved by increasing the ratio of oil. However, if there is too much oil, oil adhesion to the heat exchanger increases, decreasing the efficiency of the heat exchanger and reducing the refrigeration capacity.

To cope with this problem and to save energy, we included an oil separator; this reduces oil circulation in the system and supplies oil separately to prevent a reduction in refrigerating capacity while supplying enough lubricant to the sliding sections. This requires additional parts to separate the refrigerant and oil (centrifugal separation cylinder) and store the oil (oil sump).

In the course of developing the QS90 compressor, a direct oil return (DOR) system that is lighter and smaller than a conventional oil separator was developed to facilitate weight reduction. The DOR system was developed from original new MHI technology for the lubrication of compressors in car air conditioners, and enables the positive lubrication of sliding sections using a simple structure. **Figure 5** shows the structures of a conventional oil separator and the DOR system. In the conventional oil separator, oil mixed with refrigerant is centrifuged in the cylinder section. Then, the separated oil is kept in the oil sump and supplied to the sliding sections through the orifice. By contrast, in

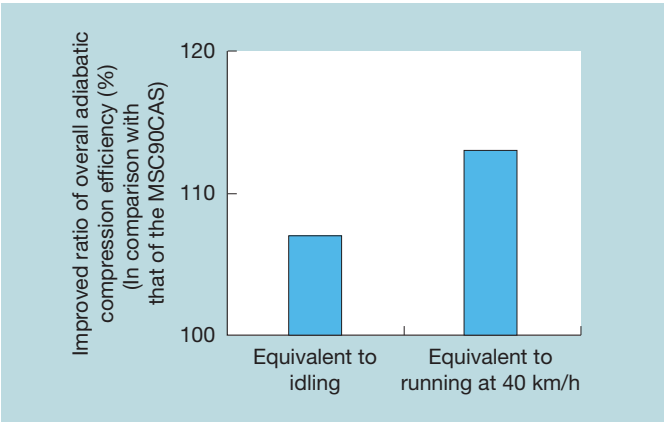

Fig. 4 Efficiency comparison between conventional and QS90 scroll compressors
Energy saving (high efficiency) was achieved by adopting the 3D scroll to reduce recompression loss.

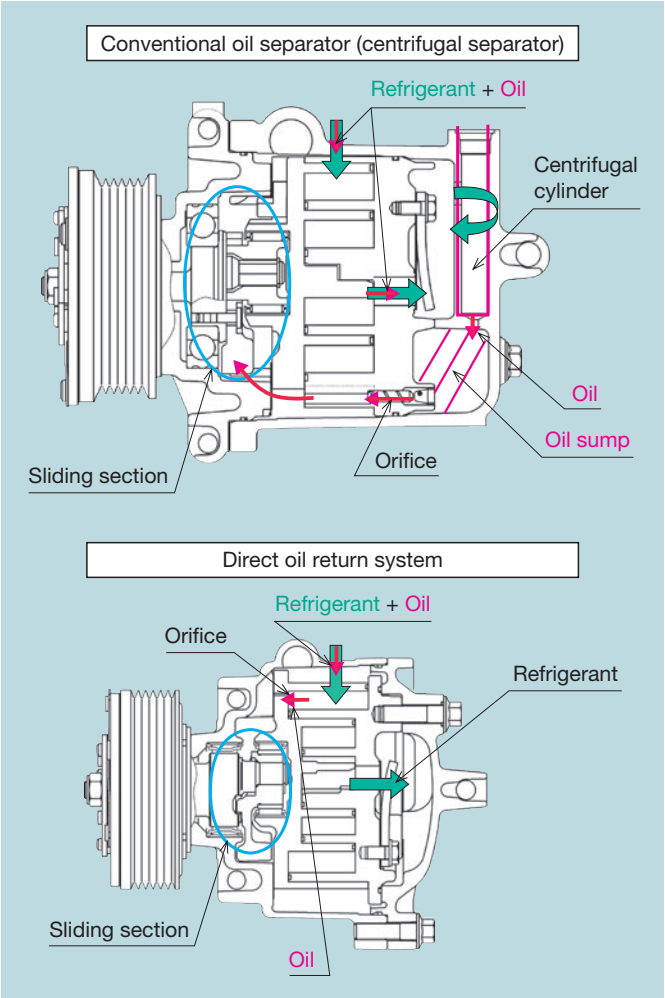

Fig. 5 Structure of a direct oil return system
The structure was simplified by supplying oil from the compression chamber to the sliding sections directly.

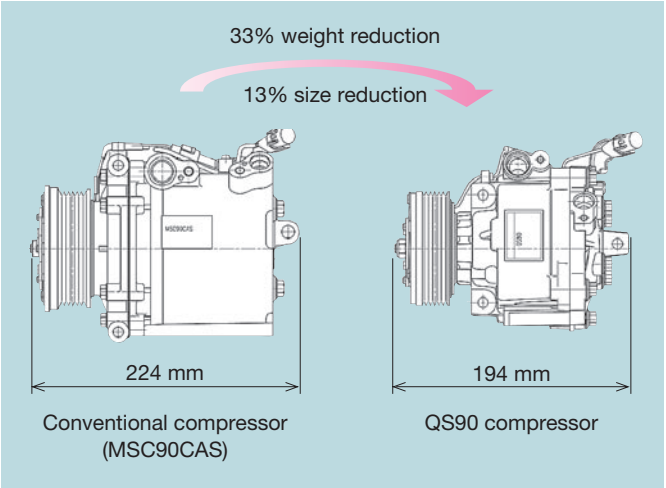

Fig. 6 External appearance of the compressor
In comparison with the conventional compressor, substantial weight and size reductions have been achieved.

the DOR system, some of the oil adhering to the inside of the compression chamber is collected by the tip of the scroll and returned from the scroll directly into the sliding sections through the orifice using the pressure inside the compression chamber. The simple construction of the DOR system does not require a cylinder to centrifuge the oil and an oil sump, both of which are necessary for a conventional oil separator.

As shown in **Fig. 6**, by adopting the DOR system and 3D scroll to reduce weight, the QS90 compressor has achieved a weight reduction of 33% and a size reduction of 13% compared to the conventional model (MSC90CAS).

5. Conclusion

MHI's original new scroll compressor (3D scroll) in combination with the new DOR oil-supply mechanism (DOR system) substantially improves efficiency and reduces weight in comparison with a conventional scroll compressor.

A joint study with Mitsubishi Motors Corporation verified the energy saving by measuring fuel consumption, using a vehicle-mounted car air-conditioning system equipped with the QS90 compressor.[3] The results led to the 2007 EPA Climate Protection Award.

While working continuously on protection of the global environment and resource conservation, MHI is determined to expand the QS compressor series from the perspective of the "environmentally friendly car air conditioner" and to supply customers with small, lightweight, highly efficient products, such as an electric air-conditioning system for hybrid or fuel-cell hybrid electric vehicles.

References

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