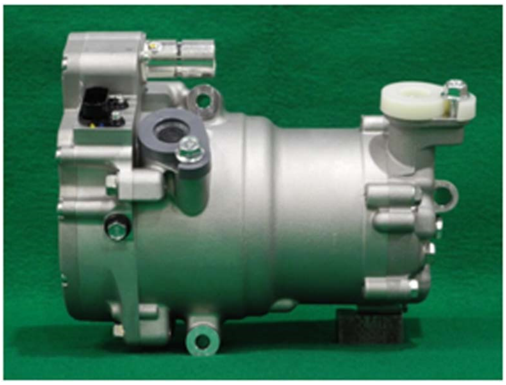
Development of Electric Compressor for Air Conditioning System of Hybrid Electric Vehicles



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With the background of environmental conservation and the reduction of CO_2 emissions, the needs for smaller size and higher efficiency are also increasing for electrically-driven compressors for vehicle air conditioning systems. For the development of a new electrically-driven compressor, we optimized the scroll specifications, reconsidered the inverter control system and made significant modifications to the internal structure of our conventional compressor. As a result, Mitsubishi Heavy Industries Automotive Thermal Systems Co., Ltd. attained an improvement in efficiency of approximately 10% and a considerable reduction in the size and weight, while also maintaining the refrigerating capacity equivalent to our conventional compressor.

1. Introduction

The market for next-generation vehicles such as electric vehicles (EV) and hybrid electric vehicles (HEV/PHEV) is expanding as the number of models from Japanese, European, and North American automobile manufacturers increases, and Chinese and venture companies enter the market. However, the circumstances surrounding the electrically-driven compressor business have become increasingly severe because of participation of new manufacturers and needs for reduction in the size and weight and improvement in the efficiency.

With the background described above, our newly-developed, electrically-driven compressor for next-generation vehicles realizes the industry's top level of size and weight reduction and improvement in efficiency. This paper presents the features of the developed electrically-driven compressor.

2. Reduction in size and weight

It is often the case that hybrid vehicles share a common engine with gasoline-powered vehicles, so the need for a small, electrically-driven compressor that can be mounted in a space for a belt-driven compressor has been increasing. For the development of the electrically-driven compressor, the structure of our conventional compressor was significantly modified with the aim of realizing a shell diameter of 123 mm or smaller and an overall length of 211 mm or shorter, the market's prevailing size. **Figure 1** compares the internal structure between our conventional compressor and the developed compressor, and **Figure 2** shows the external view and weight.

(1) Reconsideration of driving inverter location

One significant difference is that the driving inverter of the developed compressor is mounted in the axial direction of the compressor shaft, while that of the conventional compressor was mounted in the radial direction of the compressor. Because it is difficult to satisfy the target size just by changing the inverter board layout, we reduced the thickness of the inverter room by 10% as a result of a size reduction of the electronic components and a new structure of the connection between the inverter board and the driving motor to reduce the size.

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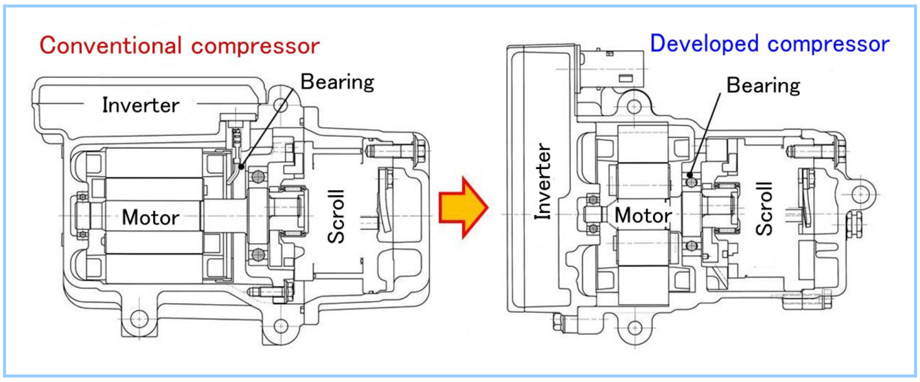

Figure 1 Comparison of internal structure

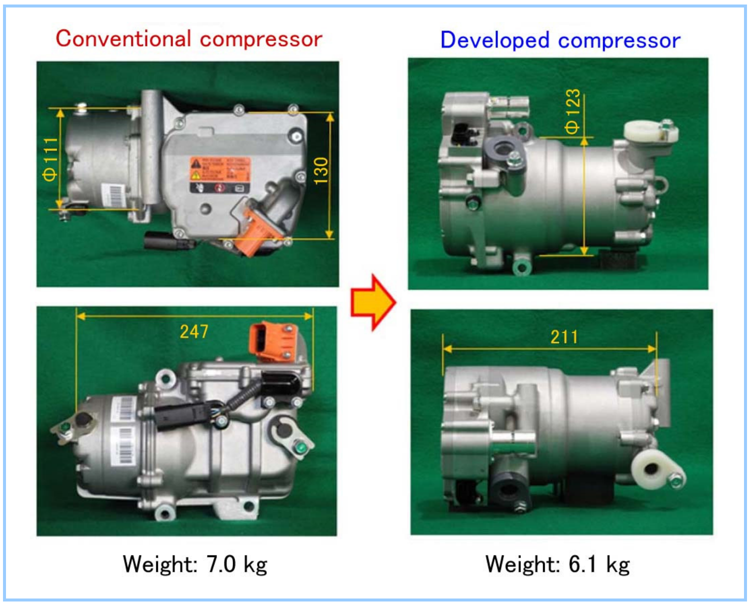

Figure 2 Comparison of appearance and weight

(2) Reconsideration of driving motor size

The motor was newly designed with reconsidered requirements in response to the new scroll specifications. We fully utilized magnetic field analysis technologies to optimize the magnet arrangement and the core shape, taking into consideration the mass productivity, in order to reduce the motor weight by 7% in comparison to the conventional motor while maintaining the motor efficiency. In addition, the specifications and arrangement of the incorporated bearings were optimized in order to reduce the overall length of the compressor without affecting the reliability of the conventional compressor.

The body was reduced in size through the efforts described above to 123 mm in shell diameter and 211 mm in overall length (Figure 2), realizing a reduction in the overall length by 36 mm and the weight by 0.9 kg in comparison with our conventional compressor. In this manner, the developed compressor attains the industry's top level of reduction in size and weight.

3. Improvement in efficiency

The electric power consumption of an electrically-driven compressor – several kilowatts – is not small and affects the fuel efficiency and electrical efficiency of the vehicle. The improvement of efficiency is required, especially in the low to middle engine speed range where the compressor is frequently operated. The developed compressor attained an improvement in efficiency by thoroughly reconsidering the specifications of the scroll, which is one of the important components of the compression area, and minimizing the leakage clearance in order to satisfy the requirements. In addition, the inverter enhanced efficiency during motor drive by adopting an electric current detection system that focuses on the efficiency in the low rotation speed range and controlling the power factor more finely.

Figure 3 shows the relation between the load condition and the maximum refrigerating capacity of the developed compressor and the conventional compressor, and **Figure 4** the coefficient of performance (COP) and the compressor rotation speed. As shown in Figure 3, the developed compressor has a refrigerating capacity equal to or higher than that of the conventional compressor in either condition. As shown in Figure 4, the COP of the developed compressor is higher than that of the conventional compressor at all rotation speeds and the efficiency improves by approximately 10%, especially in the low rotation speed range. In this manner, the developed compressor attained an improvement in efficiency while maintaining a refrigerating capacity equal to or higher than the conventional compressor as a result of our efforts described above.

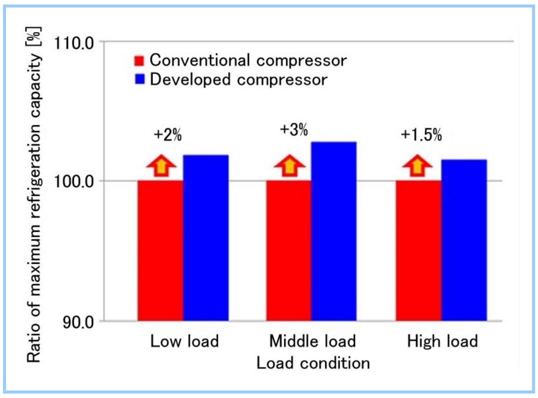

Figure 3 Comparison of maximum refrigeration capacity

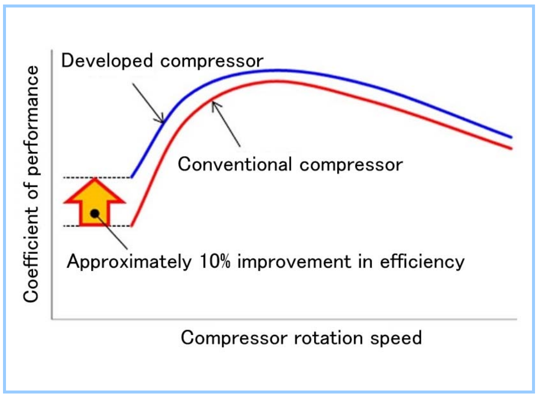

Figure 4 Comparison of coefficient of performance

4. Conclusion

Our newly-developed electrically-driven compressor for next-generation vehicles realizes the industry's top level of reduction in size and weight and improvement in efficiency due to the modification of the structure of the conventional compressor, the optimization of the scroll specifications and the reconsideration of the inverter control system. The mass production of the developed compressor will commence in 2017.