Development of High-efficiency Scroll Compressor for Automotive Air Conditioners

TAKAYUKI KUWAHARA[*1] KAZUHIDE WATANABE[*2]
MAKOTO TAKEUCHI[*3] HIROSHI YAMAZAKI[*4]
GENTA YOSHIKAWA[*5] KEITA KITAGUCHI[*5]

For the prevention of global warming, the reduction of CO_2 emissions is demanded. Under such circumstances, there are moves afoot in the automobile industry to assess and regulate the fuel consumption of automobiles when the air conditioner is operating. Therefore, Mitsubishi Heavy Industries Automotive Thermal Systems Co., Ltd. has conducted a study about the possibility of further improvement in the currently mass-produced 3D scroll compressor(note), which has the advantage of power saving by performing analysis using shape measurement and various analysis technologies. As a result, we successfully developed a high-efficiency scroll compressor that has an 11% increased refrigerating capacity under conditions equivalent to the idling of the automobile, while keeping the weight and size equivalent to those of the conventional 3D scroll compressor.

(Note) "3D scroll" is a registered trademark of Mitsubishi Heavy Industries, Ltd.

1. Introduction

With the increasing interest in protecting the global environment and the regulation of the CO_2 emissions and fuel consumption of automobiles, the development of fuel efficiency increasing technologies has been accelerated.

Automobile fuel efficiency is generally measured and assessed in a specified running pattern, like JC08 mode in Japan, without operating the electrical equipment such as the windshield wipers, lights or air conditioner. On the other hand, in actual running, the degree of effect of the use of the electrical equipment – especially the air conditioner – on fuel consumption has been comparatively increasing along with recent increases in engine efficiency. Under such circumstances, in the United States, there have already been efforts to assess and regulate the fuel consumption in a state close to actual running by adding the running pattern during the operation of the air conditioner to the test cycle for measuring fuel consumption.

At present, many of the air conditioners mounted on automobiles are systems using the vapor compression type refrigerating cycle, which is comprised of a compressor, condenser, expansion valve and evaporator. Most of the power consumed by the air conditioner is used by the compressor which plays the role of a pump for circulating the refrigerant in the refrigeration cycle. Therefore, in order to improve the fuel efficiency during the operation of the air conditioner, the power saving of the compressor is indispensable. The vehicle interior space has been expanded in recent years, and in addition, the diameter of crank pulley has become smaller (the weight has been reduced) and the engine speed has been reduced for the improvement of fuel efficiency on the vehicle side. As a result, the improvement of refrigerating capacity and efficiency in a low-revolution range such as at idling has been strongly demanded. This is particularly true for belt driven compressors that receive power from the engine via a belt.

We put the 3D scroll compressor (QS compressor), which has a power saving feature, on the

*1 Engineering Department, Mitsubishi Heavy Industries Automotive Thermal Systems Co., Ltd.
*2 Manager, Engineering Department, Mitsubishi Heavy Industries Automotive Thermal Systems Co., Ltd.
*3 Chief Staff Manager, Research & Innovation Center. Mitsubishi Heavy Industries, Ltd.
*4 Chief Staff Manager, Machinery Research Department, Research & Innovation Center. Mitsubishi Heavy Industries, Ltd.
*5 Machinery Research Department, Research & Innovation Center. Mitsubishi Heavy Industries, Ltd.

market in 2007 and has contributed to the improvement of automobile fuel efficiency during actual operation. This paper reports about the high-efficiency scroll compressor (QSH compressor) which was developed through the further improvement of the conventional 3D scroll compressor.

2. Features of 3D scroll compressor

The compression principle of the 3D scroll compressor is shown in **Figure 1** and **Figure 2**. In the scroll compressor, along with the revolution of the orbiting scroll, the crescent-shaped compression chamber moves from the outer side to the inner side while reducing the volume, thereby continuously compressing and discharging the refrigerant. At this time, in the 3D scroll compressor where the wrap height on the inner side is lower than on the outer side, the refrigerant can be compressed not only in the radial direction, but also in the axial (height) direction, and a high compression ratio and superior power saving performance can be obtained.

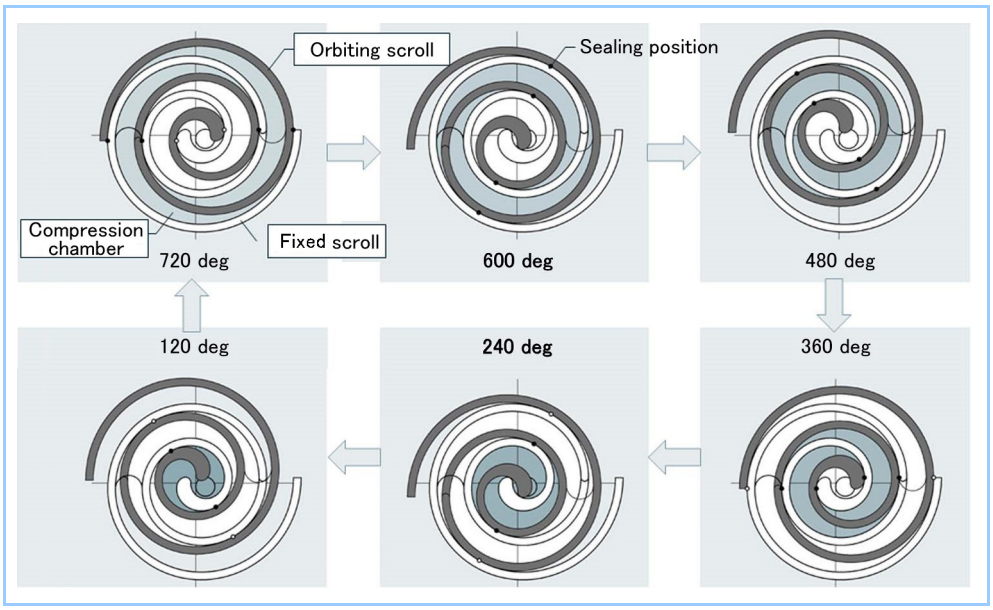

Figure 1 Compression principle (1) of the 3D scroll compressor
The compression chamber moves from the outer side to the inner side while reducing the volume.

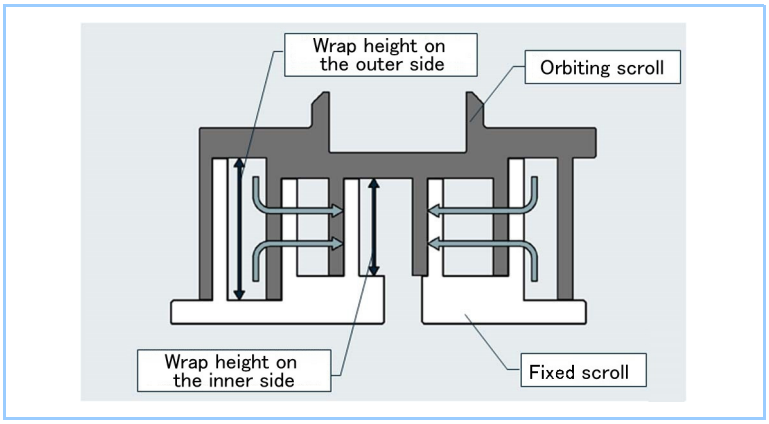

Figure 2 Compression principle (2) of the 3D scroll compressor
The compressor can also compress in the axial (height) direction from the outer periphery side toward the inner periphery side.

3. Analysis and improvement

Analysis and improvement were conducted for the purpose of reducing leakage occurring in the compression process in order to realize the improvement of the refrigerating capacity and efficiency.

3.1 Analysis of leakage

The clearances which cause leakage are shown in **Figure 3**. The tip clearances are clearances at the wrap end face and bottom face of the scroll, and the mesh clearances are clearances among wrap side faces. As shown in the compression principle of Figure 1, in the scroll compressor, the

seal position moves from the outer side to the inner side with progress of the compression process. In addition, the shapes of the scroll and other supporting components which cause the formation of the clearances are affected by deformation due to processing accuracy, bolt tightening, etc. Therefore, in order to conduct a detailed analysis of leakage occurring during the compression process, it is necessary to quantitatively understand the continuously changing clearances by this seal position. The authors quantified the clearances using the scanning measuring function, etc., of a coordinate measuring machine, and the relationship between clearance and leakage in the compression process was continuously understood by both analysis and experimental approaches.

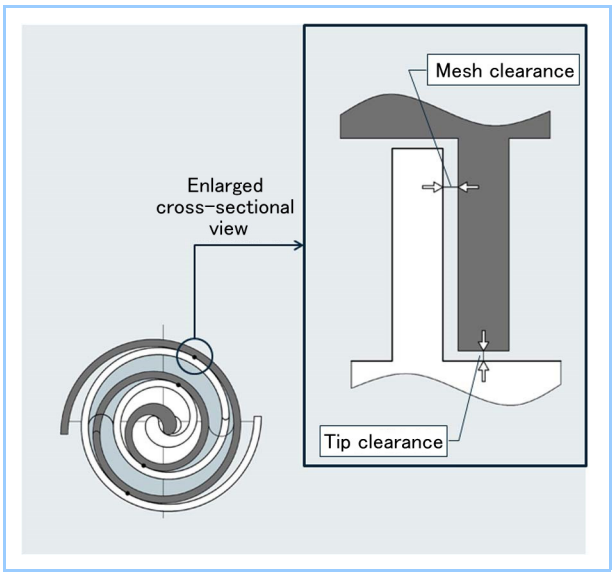

Figure 3 Clearances which cause leakage

3.2 Reduction of leakage by reduction of clearance

Since the relationship between clearance and leakage was clarified, the clearances in the sections significantly affecting the total amount of leakage occurring during the compression process can be positively reduced through the improvement of the scroll profile. An analysis of the amount of leakage in a conventional compressor and the newly developed compressor is shown in **Figure 4**. The reduction of clearance reduces the amount of leakage to half or less, and it is expected that improvement in the refrigerating capacity and efficiency can be realized.

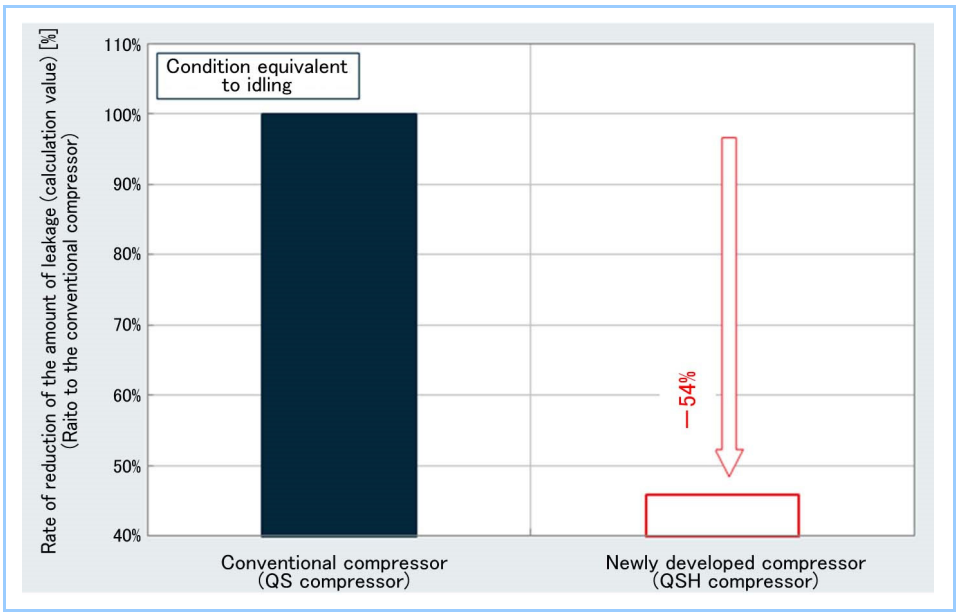

Figure 4 Analysis of the amount of leakage in a conventional compressor and the newly developed compressor

4. Effect of improvement

To examine the improvement effect, the performance was compared between the conventional compressor and the newly developed compressor.

4.1 Comparison of unit performance

A comparison of refrigerating capacity under conditions equivalent to idling of the automobile is shown in **Figure 5**.

The refrigerating capacity of the newly developed compressor is increased by 11% compared with that of the conventional compressor.

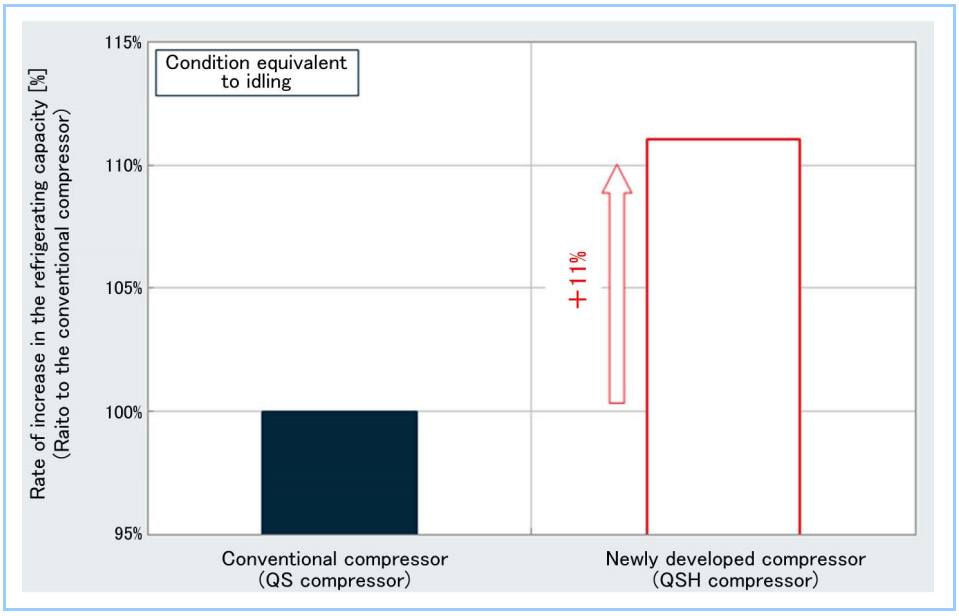

Figure 5 Comparison of unit performance

4.2 Comparison of air conditioner blow-off temperatures when the compressors are mounted on an automobile

With the compressors mounted on a C-segment automobile (practical vehicle with an overall length of 4200 mm to 4500 mm), the measurement and comparison results of the blow-off temperatures during idling are shown in **Figure 6**.

Since the refrigerating capacity was increased in the newly developed compressor, the blow-off temperature was reduced by 2.7°C compared with the case where the conventional compressor was mounted.

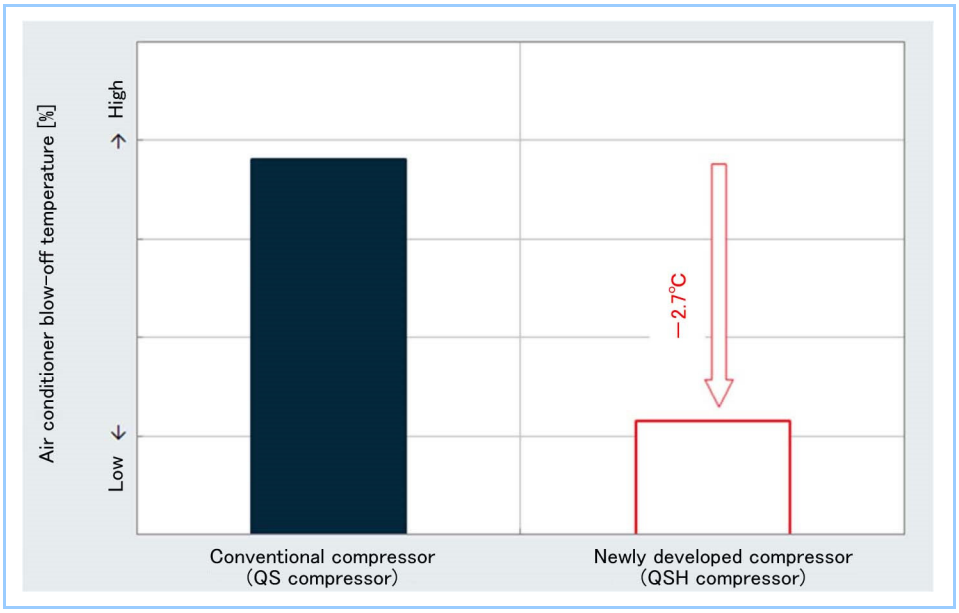

Figure 6 Comparison of air conditioner blow-off temperatures when the compressors are mounted on an automobile

4.3 Comparison of fuel efficiency when the compressors are mounted on an automobile

In the same way, the fuel efficiency was measured and compared using the running pattern during the operation of the air conditioner which is adopted in the measurement of fuel consumption in the United States. The results are shown in **Figure 7**.

With the reduction of loss associated with leakage, etc., the fuel efficiency in the case where the newly developed compressor is mounted is improved by 3% compared with that where the conventional compressor is mounted.

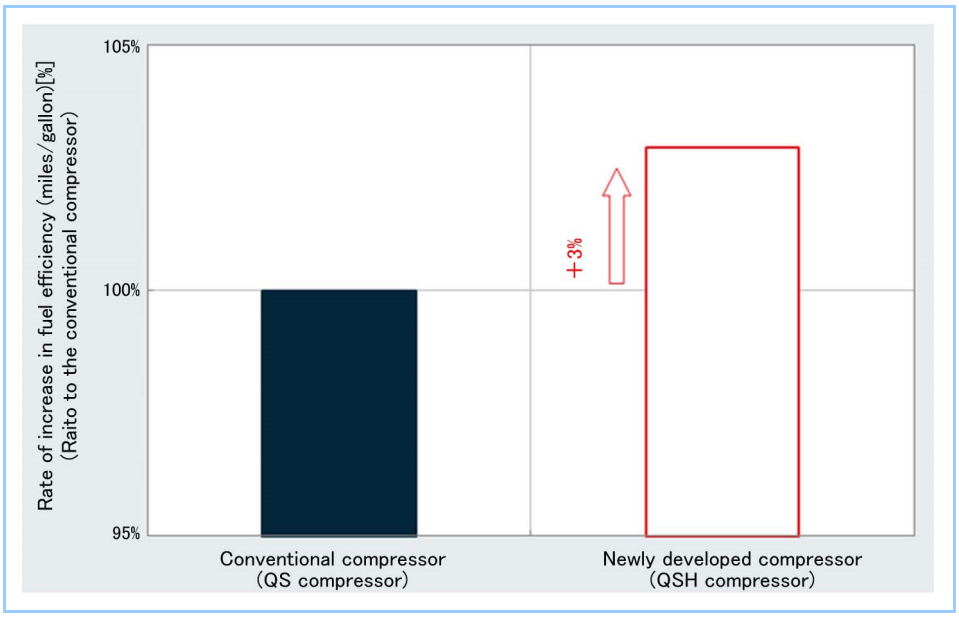

Figure 7 Comparison of fuel efficiency when the compressors are mounted on an automobile

5. Conclusion

Mitsubishi Heavy Industries Automotive Thermal Systems Co., Ltd. developed a high-efficiency scroll compressor with a substantially increased refrigerating capacity during the idling of the automobile by reducing leakage in the compression process, while using the superior power-saving performance of the conventional 3D scroll compressor.

We will continue technological improvements in the future as well, and will make efforts to develop and spread the use of products that can contribute to the protection of the global environment. The mass production of the newly developed compressor described in this paper is planned to be started in 2019.