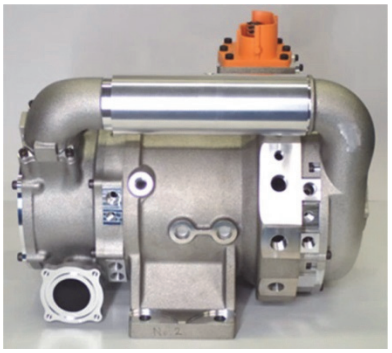
High-Efficiency Electric Compressor that Improves Decarbonization Technology and Fuel Cell Performance



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As the global movement accelerates toward the realization of a decarbonized society, the mobility industry has a growing need for electrification of vehicle powertrains. In order to expand the electric vehicle market in the future, it is necessary to solve issues such as higher battery performance and fast charging technology. In recent years, fuel cell systems that can extract electric energy directly from clean hydrogen fuel and achieve high power generation efficiency have attracted attention as the most effective means of zero emissions.
Fuel cell systems can be applied to vehicles, stationary and other industrial applications, and are expected to become widely used after 2030 with the provision of hydrogen infrastructure. It is also incorporated into long-term policies of countries around the world, and continuous market expansion is expected. Mitsubishi Heavy Industries Engine & Turbocharger Co., Ltd. (MHIET) has developed a highly efficient electric compressor for fuel cell systems to meet the changing business environment of shifting from internal combustion engine vehicles to zero-emission vehicles, and has begun supplying samples to customers. Widespread use of hydrogen infrastructure takes time, and it is expected that the infrastructure will be developed first for limited applications such as transportation between bases. This report introduces the product specifications and features of the high-efficiency electric compressor for commercial vehicles.

1. Introduction

With the global trend of decarbonization, the volume of electric vehicles is expected to increase year by year. On the other hand, electric vehicles in the commercial vehicle field have a problem of load reduction due to larger batteries. The demand for fuel cell systems using hydrogen fuel is expected to increase as one of the countermeasures. **Figure 1** is a diagram of a vehicle system with fuel cells. The electric compressor under development is an important component in fuel cell systems that supplies compressed air into the stack and obtains electrical energy by chemical reaction with hydrogen fuel. According to the market analysis of MHI-ET, the size of electric compressors for fuel cell vehicles is expected to expand mainly in the 3 regions of China, Europe and North America, and the motor output of 20~30 kW for pickup trucks and medium-duty trucks will occupy the majority of the market in 2045. For the fuel cell stack with the highest need of 150 kW, a motor output of 30 kW is required. In addition, for heavy-duty trucks with a fuel cell stack output of 200 kW or more, 2 electric compressors are used in parallel. MHI-ET is being developed with a view to customer needs that can be met by a single electric compressor. Electric compressors contribute the most to the overall efficiency of fuel cell systems, and it is necessary to develop high-efficiency electric compressors that are adapted to the needs required by the products.

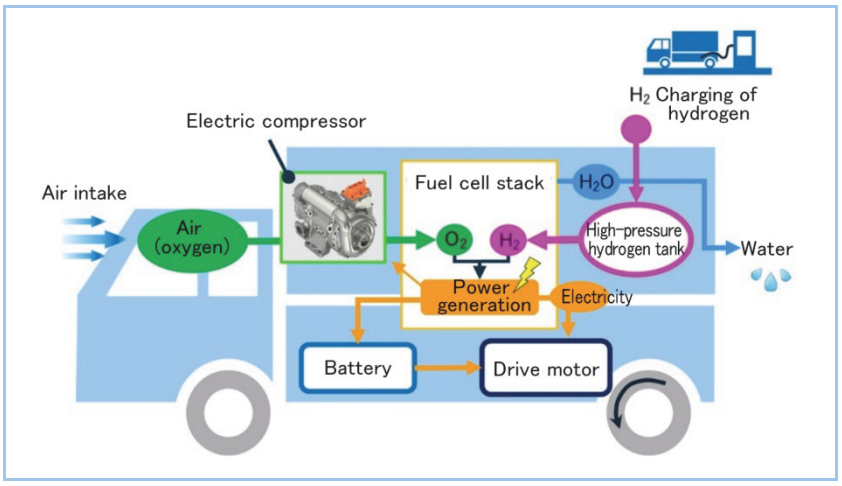

Figure 1 Diagram of vehicle system with fuel cells

2. Product specifications

Figure 2 shows the exterior view of the developed electric compressor, and Table 1 shows the specifications. Our target fuel cell stack output range for commercial fuel cell vehicles is 120-150 kW, which is most needed by the customers. The product has the specifications of a maximum DC voltage of 850 V, motor output of 25-30 kW, and 100 krpm or more. A water-cooling system is mainly used in the motor/inverter, while an air-cooling system using compressed air is employed in the rotor magnet and the foil air bearing, which are the heat-generating components in the motor. Moreover, oil-free foil bearings are used to prevent poisoning of fuel cell stacks. Figure 3 shows the outline of the development of the electric compressor series. Our goal is to contribute toward the achievement of a carbon neutral society by offering a product lineup with a fuel cell stack output range of 100-300 kW, thereby meeting a wide variety of needs from small commercial vehicles to heavy-duty trucks to marine vessels.

Figure 2 Exterior view of developed electric compressor

Table 1 Specifications of developed products

Item	Specifications
Maximum voltage	DC850V
Rated motor output	25-30 kW
Motor type	Permanent magnet
Cooling system	Water cooling
Bearing type	Foil bearing

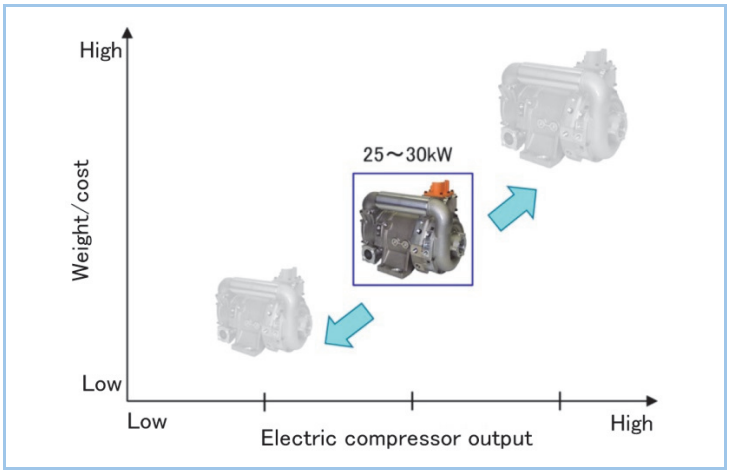

Figure 3 Outline of development of electric compressor series

3. Product features

Electric compressors developed for fuel cell systems have the following features. MHI-ET has been developing electric compressors for some time and is currently developing the second generation. **Figure 4** shows a comparison of the features and appearance of the developed products.

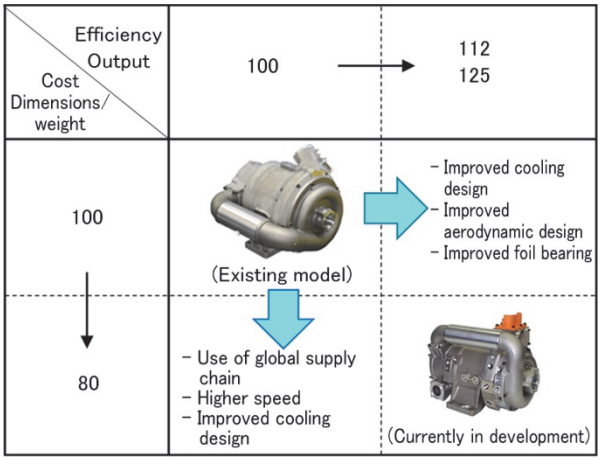

Figure 4 Comparison of features and appearance of developed products

(1) Higher efficiency

Electric compressors for fuel cell systems are driven using electric power generated by fuel cells. Therefore, higher efficiency of the electric compressor itself is an important factor directly linked to higher efficiency, smaller size and lower cost of the entire fuel cell system. In this structure, high-pressure compressed air is supplied to the fuel cell stack by supercharging in two stages sequentially with two compressors at each end, thereby realizing high flow rate and high pressure while minimizing the size of electric compressors. In addition, the technology established in the turbocharger business has enabled a more advanced aerodynamic design and more efficient compressor wheels. Furthermore, with a balanced design between the thrust load generated by the two compressor wheels of both ends and the foil air bearing, mechanical loss has been reduced to elevate the efficiency of electric compressors. The type of motor used is a permanent magnet motor with distributed windings suitable for high-speed revolution and high efficiency applications.

(2) Higher output

Electric compressors for vehicles are required to be smaller and lighter due to restrictions on their loading locations and effects on fuel consumption. On the other hand, our company realized the design of high-speed rotation, which reduced the required driving torque and enabled smaller motor designs. Higher output has also been realized with a balance design including the appropriate enhancement of cooling for the motor housing and the inside of the motor, and the minimization of pressure loss in the bypass of compressed air from the compressor.

(3) Higher durability

When oil leaks from the bearings and reaches the fuel cell stack, poisoning occurs resulting in declining performance and shortened life of the stack. Oil-free foil air bearings are applied to electric compressors for fuel cell systems, but ensuring the durability of foil air bearings is also an important point of electric compressor durability. Our company has the design, manufacturing and quality control know-how of rotary rotors accumulated in the production of turbochargers. Therefore, it is possible to design and manufacture a stable rotor with less vibration to ensure durability. Especially when the motor is started, the foil air bearing rotates in contact with the shaft. However, since it floats in contact up to a certain number of revolutions, a highly abrasion-resistant coating is applied to achieve both bearing function and durability. In addition, the company has established an insulation design that can handle high voltage DC of 850 V and an evaluation method for the design, thereby contributing to the improvement of motor reliability.

(4) Lower cost

Fuel cell systems are expected to play an important role in realizing a decarbonized society, but they are also required to be economical. We have already introduced a pilot production machine and have adopted the design and manufacturing method for the mass production process, so that the cost can be reduced according to the specifications required by automobile manufacturers. Moreover, in addition to the specification work for cost reduction, the global supply chain established through the turbocharger business is utilized for cost reduction. Such features are based on the needs understood through various types of market research/analysis and engagement in dialogue with customers, as well as our rotor technology cultivated in the turbocharger business.

4. Future prospect

Our product development is also aimed at making the following options available: a single-stage type for cost reduction, and an expander type for enhancing the efficiency of the entire system by recovering energy from the fuel cell exhaust during high load operations. Production of the high-efficiency electric compressor for commercial vehicles introduced in this report is expected to begin in 2025. MHI-ET develops products for fuel cell systems according to market needs, thereby contributing to the achievement of a decarbonized society.