Motor Drive System for i-MiEV and Standard Type Motor Drive System for Electric Vehicle (EV)

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Keywords Electric Vehicle (EV), CO_2 reduction, Fast response current control, Low noise

Abstract

Meidensha Corporation has supplied motor drive systems for Mitsubishi Motors Corporation's electric vehicles, i-MiEV. Mitsubishi Motors started the serial production of Electric Vehicle (EV) in 2009 for the first time in the world. Our motor drive system product realized high efficiency, high reliability, and low noise. In addition, we also succeeded in designing a compact size and light mass.

We have additionally developed the new capacity series of 3 types as the standard type motor drive system for EV. We are expanding the application field for a variety of cars from kei cars (660cc class model) to 2000cc class car.

1 Preface

With a sudden increase in energy demand resulting from rapid economical growth of emerging nations, we expect that crude oil prices will remain high. Dependence on crude oils is about 40% of the primary energy supply in Japan[(1)] and almost 100% in transportation sectors[(2)].

Furthermore, from the viewpoint of the Climate Change, reduction of CO_2 emission is in demand. In Japan, CO_2 emission from transportation sectors accounts for about 20% of the whole. When limited to the field of transportation alone, CO_2 emission from cars amounts to almost 90% of the total[(3)]. This fact suggests that we should dedicate ourselves to the reduction of CO_2 emission focused on cars.

In order to respond to the rising issues regarding energy-related restrictions and environmental challenges, automotive industries are expected to develop next generation products to popularize electric vehicles, and hybrid cars, on top of the development of energy efficient models for internal combustion engine cars. Shortly after the Great East Japan Earthquake in 2011, electric vehicles played a double role: they served not only as a means of mobility but also as a power supply. Given the aforementioned, there are growing interests in electric vehicles for the new values indicated.

Against the aforementioned technical background, the world expects electrical manufacturers to contribute in solving the above challenge through the development and supply of products like motor drive systems for the next-generation cars.

We started the supply of motor drive systems for Mitsubishi Motors Corporation's electric vehicles i-MiEV in 2009 as the world's first serial production of EV. Later, we extended our product supply to MINICAB-MiEV (**Fig. 1**) and to Peugeot S.A. (for "iOn" model) and CITROËN (for "C-ZERO" model) through Mitsubishi Motors. Going forward, we will promote development programs for further performance improvement to meet various requirements from automakers by expanding our application to various types of cars.

This paper provides the outline on the features of the currently supplied motor drive system for i-MiEV and also the standard type motor drive system for EV presently under development.

Fig. 1 MINICAB-MiEV by Mitsubishi Motors Corporation

The photo shows an electric vehicle where Meiden's driving motor and controller are installed.

2 Motor Drive System for i-MiEV

Unlike the performance of equipment for general industries, the motor drive system for EV is required to ensure unique and specific characteristics, durability against rigorous environmental conditions, and high reliability. In order to meet all of these requirements, we investigated various new technologies and expertise during the development of our products. At the same time, we conducted through verification tests on reliability. Our technical achievements gained during the development of these products and their features are described here. Fig. 2 shows the driving motor for i-MiEV and Fig. 3 shows an external appearance of the controller.

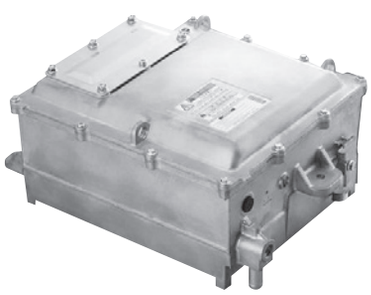
2.1 High Accuracy and High Response

Unlike ordinary cars driven by internal combustion engines, electric vehicles do not have any transmission. The driving motors and controllers incorporated in electric vehicles are required to ensure wide and constant output characteristics up to the range of high speeds. In addition, high-torque characteristics are called for in the low speed range. Table 1 shows the specifications of driving motors and controllers for i-MiEV. For our products, we have developed the PM motor that ensures high accuracy for vector control. This PM motor is demonstrating high-accuracy and high-response motor control throughout the speed range.

Source: Website of Mitsubishi Motors Corporation

Fig. 2 Driving Motor for i-MiEV

An external appearance of i-MiEV driving motor is shown.



Source: Website of Mitsubishi Motors Corporation

Fig. 3 Controller for i-MiEV

An external appearance of i-MiEV controller is shown.

2.2 Low Noise

Compared with internal combustion engines, the motor noise level is extremely low; however, electric vehicles are primarily required to offer outstanding quietness than internal combustion engine cars. The driving motors for EV are therefore, strictly required to lower their noise level. To clear such a target, we introduced reinforcing ribs and optimally distributed them over the motor frame surface. As a result, membrane vibration was greatly reduced and this led to a remarkable reduction of motor noise generation. This noise reduction contributes greatly to the quiet ride.

2.3 Compact Size, Light Mass, and High Efficiency

One of the challenges of EV is the short driving distance. To solve this problem, it calls for light mass and high efficient model for motor drive system for EV. Since many components must fit in a limited space, the carmaker put dimensional limitations on each component.

In order to meet these requirements, by drawing on our latest electromagnetic field analysis technology to optimize permanent magnets layout, we made our motor into compact size, light mass, and high efficiency. For the improvement of cooling performance, an aluminum hollow frame with a water

Table 1 Specifications of Motor Drive System for i-MiEV

Specifications of Motor Drive System for i-MiEV are shown.

Type	Water-cooled permanent magnet type synchronous motor Water-cooled PWM controller
Max. output	47kW (3000～6000min^{-1})
Rated output	25kW
Max. torque	180N·m (0～2000min^{-1})
Battery voltage	330V

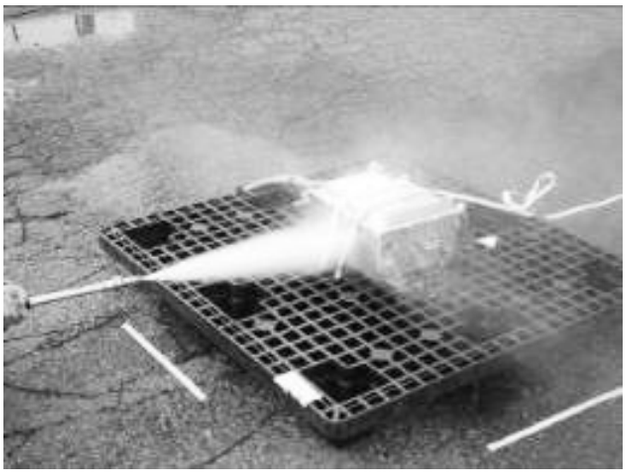


Fig. 4 High Pressure Cleaning Test

A view of high pressure cleaning test is shown.

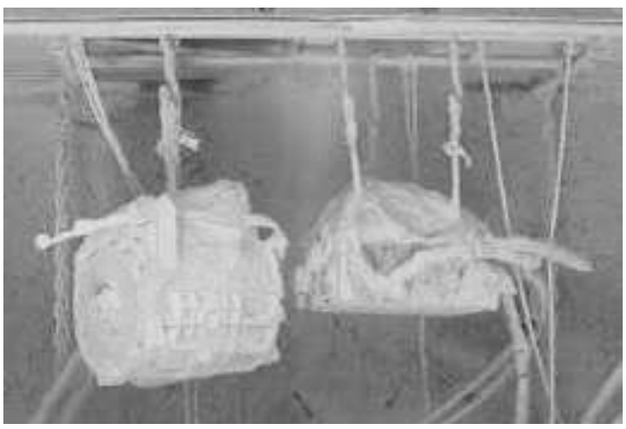


Fig. 5 Dust Test

A view of dust test is shown.

Fig. 6 Waterproof Test

A view of waterproof test is shown.

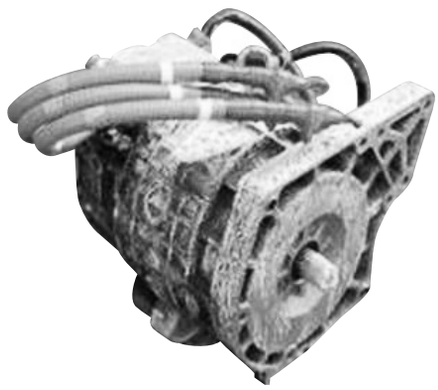


Fig. 7 Salt Spray Test

A view of salt spray test is shown.

jacket has been adopted. This idea led to the success on further compact and light mass models.

For controllers on the other hand, a dedicated Insulated Gate Bipolar Transistor (IGBT) jointly developed with a semiconductor supplier is adopted. At the same time, parts and components in the main circuit were distributed in an optimal layout to realize a snubber-less feature under an optimal design for cooling. As a result, we could realize high reliability, compact size, and light mass model for in-vehicle usage.

Our motor drive system then became compact, light, and highly efficient in order to realize a longer driving distance.

2.4 High Reliability

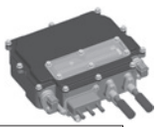
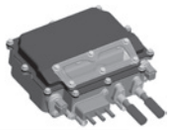
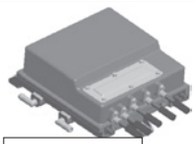
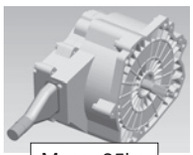
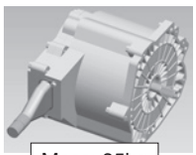
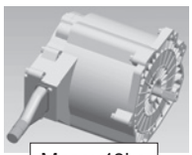
In order to meet rigorous requirements imposed on motor drive system for EV, we promoted development of beta products by doing preliminary evaluations on parts and materials. At the final stage of development, we made thorough reliability verification tests. Such testing works required large amounts of labor and time. By meeting all the reliability requirements, we could support the total high reliability of EVs. **Figs. 4** to **7** show some examples of reliability verification tests.

3 Standard Type Motor Drive System for EV

We are now also developing a motor drive system for EV. According to the current schedule, three types of capacity series are being developed. These products will be applicable to a variety of cars from Kei cars (660cc class model) to automobiles of 2000cc class. **Table 2** shows the outline of the

Table 2 Specifications of Standard Type Motors and Controllers for EV

Specifications of standard type motors and controllers are shown for electric vehicles.

30～40kW (Light vehicles)	50～60kW (Light vehicles)	80～90kW (Medium-sized car class)
EV･PHEV･HEV	EV･PHEV	EV･PHEV
 Volume: 3.5L	 Volume: 4.6L	 Volume: 6.5L
 Mass: 25kg	 Mass: 35kg	 Mass: 40kg
Max. output: 30kW-75N･m-3820min^{-1} Max. rotation speed: 12,000min^{-1}	Max. output: 60kW-150N･m-3820min^{-1} Max. rotation speed: 12,000min^{-1}	Max. output: 80kW-200N･m-3820min^{-1} Max. rotation speed: 12,000min^{-1}

capacity series. **Figs. 8** and **9** show external appearances of the 60kW class.

Like i-MiEV, the adopted driving motor is a permanent magnet type synchronous motor that could realize industry-leading compact, light mass, and high efficient design. The permanent magnetic type synchronous motor uses rare earth elements such as neodymium, dysprosium. They, however, tend to suffer the market volatility by the Chinese Government's rare earth policy change since most of the rare earth elements are from China. Therefore, in order to minimize the rate of use of such rare earth materials, we researched the most optimal shapes of rotors and stators by drawing on our electromagnetic field analysis technology. We selected a magnet using less dysprosium; we researched the magnet structures in order to reduce the magnet's temperatures. Through these efforts, we conduct our R&D program to minimize the price volatility risk of rare earth materials.

In regard to controllers, we promote our research focusing on more compact and light mass designs. We are expecting a substantial reduction of size and mass by adopting directly water-cooled IGBTs, reexamining the whole circuit configuration and all its parts used, and we made an optimum layout design of parts.

In terms of production, we are about to realize three types of capacity series production by the same robot assembly line to maintain stable quality and efficient production.

Fig. 8 Standard Type Motor for EV

We realized a substantial reduction of use of rare earth materials.

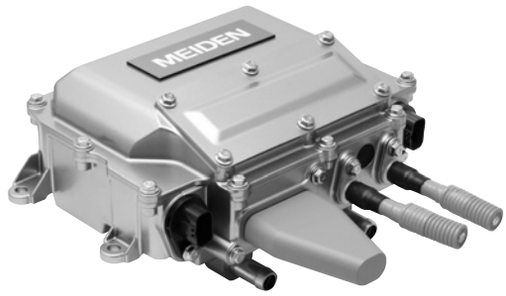


Fig. 9 Standard Type Controller for EV

We realized a remarkable compact and light mass design.

As described above, our development programs will realize more high performance motor drive system offerings. These new models will be applicable to various car models thus we will be able to meet various requirements of carmakers.

4 Postscript

Ahead of our competitions, we began to manufacture the permanent magnet type synchronous motors in the 1960s. We are a pioneer (world's first) in realizing the serial production of motor drive system for EV in 2009. In addition, we have a rich history of developing motor drive systems for hybrid cars, in-wheel motors, and induction motors.

Going forward and drawing on our long-term engineering resources, we will promote further innovations in technologies and product development, and would like to propose effective motor drive systems for next-generation cars like EVs and

hybrid cars. While meeting various requirements of automakers for greener cars, we will contribute to solving issues regarding energy-saving and Climate Control.

《**References**》

(1) BP Statistical Review of World Energy June 2011
(2) Ministry of Economy, Trade and Industry: "New National Energy Strategy," 2006.5
(3) Ministry of Economy – Next Generation Car Research Society: "Next Generation Car Strategy 2010," 2010.4.12