1. Introduction

In the automobile industry, the ratio of electric vehicles to the automotive sales is significantly growing year by year for the sake of energy-saving and global warming prevention. PCU (Power Control Unit) for driving motors is essential for electric vehicles and the function and performance required of PCU are becoming higher every year.

In addition, market needs for electric vehicles widely vary from compact cars to large cars and the variations of motor output and the number of motors are increasing. This document describes a PCU for electric vehicles having three drive motors.

2. PCU Overview

Fig. 1 shows the structure of our PCU for three motors. The newly developed PCU makes the maximum use of ECU (Electronic Control Unit) which controls the PCU with external signals and a SUB-COMP comprising a power semiconductor, insulated substrate and lead frame developed in PCU for the base model two-motor hybrid system.

As shown in Fig. 2, three motors can be driven now with UVW phase × 3 set configuration and two ECU configuration to realize a PCU which can control three-motor vehicles. The PCU has neither booster function nor generator function due to the specification of the vehicle.

The PCU has a built-in DCDC converter (hereafter DCDC) to step down battery voltage to 12V. While conventional PCU required a separate cooling function to cool down an externally installed DCDC converter, new PCU can use the cooling channel of the PCU owing to the converter built in the PCU to simplify overall vehicle structure.
3. Two-Part Die-Cast Case

As shown in Fig. 3, conventional aluminum die-cast case has a four-layered structure (upper cover, upper case, middle case, lower case) with an IPM and a reactor fitted on the top and the bottom surfaces of the middle case to require heat dissipation. In the developed model, aluminum die-cast case is separated into two parts.

As shown in Fig. 4, the number of die-cast parts is reduced from four to two parts to contribute to cost cutting and weight saving by employing a two-part casing structure where components are stuck and fixed on the lower case and protected by the upper cover. In addition, without fixing the components on the top and bottom surfaces of the middle case, the inversion step in the PCU ASSY process is eliminated. Furthermore, assemblability is improved by fixing the ECU board on a tower structure resin bracket which enabled to assemble the components by stacking from the bottom layer on the lower case.

The die-cast case is so large as 272 (mm) × 792 (mm) (approx. 1.5 times the size of conventional case) and only a limited number of manufacturers possess die-casting equipment capable of coping with that size. The cutting amount (machining allowance) is determined and reflected in the design of dies considering overall distortion of the case which causes variation in the flatness of the mating surfaces of the case and the cover to affect the sealing.

4. Sealing (Series Cooling Channel)

Since the PCU incorporates a DCDC in addition to an IPM which is a heat generating component in the conventional model, it is required to remove heat generated from those components with coolant to prevent overheating. DCDC and IPM cooling channels are connected in series in the new PCU since an easy-to-manufacture simple structure is required for formability of a large cast body.

As shown in Fig. 5, the series cooling channels are arranged in the order from ① DCDC cooling channel → ② Lower case channel → ③ W/J of IPM → ④ Lower case channel. In sections from ② to ③ and ③ to ④ within PCU, O-ring structure same as that of the PCU for the base model two-motor hybrid system is employed to meet the requirements for actual vehicles to prevent LLC leakage as overall sealing performance of the series channels.

Since DCDC cooling channel ① is directly
exposed to external environment of the PCU, it shall meet the requirements for weather resistance of actual vehicles in addition to the sealing performance. For this reason, FIPG (Formed In Place Gasket) is employed for its higher weather resistance than O-ring. Detailed DCDC cooling part is shown in Fig. 6 and 7.

The DCDC cooling part employs an easy-to manufacture flow channel structure where a heat dissipation water channel is provided in the lower case and a Water Jacket is installed from outside the PCU. To meet the requirements for sealing and weather resistance, FIPG is applied between the lower case and the Water Jacket. A step is formed in the FIPG application surface on the lower case to prevent intrusion of FIPG into the LLC channel.

5. High-Frequency Oscillation

Since the PCU controls large power with high-frequency wave, internal elements of the condenser oscillate at a high frequency. The oscillation is transmitted to the vehicle body through the PCU case to affect the silence in the vehicle cabin. As a countermeasure for the noise, oscillation in the frequency band which caused a problem is reduced by moving the resonance point of oscillation changing the shape of the fixing bolts of the oscillation generating condenser and the oscillation transmitting PCU case. (See Fig. 8.) Furthermore,
since different shape and weight of bolts are expected to have an effect to reduce oscillation in a different frequency band, it is possible to take a measure with a minimal design change according to the conditions.

6. Noise

Since PCU generates noise in ringing by IGBT switching, taking a measure is required to reduce noise level in the frequency band causing a problem. Fig. 9 shows the impedance frequency characteristic of Y condenser of which resonance point is 10 to 20 MHz. As shown in Fig. 10, noise emission level from PCU is reduced by placing the resonance point F in the targeted frequency band adjusting capacitance C and the wiring length L.

7. Future Prospects

Employing design for commonality in SUB-COMP and MOT ECU enables deployment of variants of the PCU to various electric vehicles.

We intend to contribute to value creation of electric vehicles by providing products with higher performance and reliability making use of the sealing technology, high-frequency oscillation reduction technology and noise reduction technology we cultivated through the development of the new PCU for electrification of vehicles which will further be accelerated in the future.

References


Author

T. NAKAMURA

I would like to express my gratitude to the members of Honda R&D Co., Ltd. and component makers for cooperation in the development of the PCU. In conclusion, it is thanks to commitment of all persons involved as well as the project members that we finally reached mass production overcoming various difficulties. I would like to sincerely ask you for continued support for development of higher performance PCU. I really thank you for your cooperation. (NAKAMURA)