

Development of Li-ion Battery for SPORT HYBRID

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ABSTRACT

A lithium-ion battery was developed to meet the performance required by Honda SPORT HYBRIDs.

The surface area of the electrode was expanded and the amount of active material applied was increased to enhance cell performance. This achieved 63% higher output at -10°C and 26% higher output and 6% higher capacity at 25°C compared to the previous cell. In addition, mounting compatibility with existing vehicles was realized by keeping the same cell outline dimensions and voltage behavior. The module length in the cell stacking direction was reduced by 7% compared to the previous structure by changing the materials and shapes of the end plates and frames, and by changing the structure used to hold the cells.

1. Introduction

Petroleum resource reserves are finite, and there are concerns over depletion. In addition, the continuous evolution of technology to increase automobile fuel efficiency is also necessary from the viewpoint of effective use of resources. However, customer demands for automobile product appeal are diversifying, and the need to provide driving enjoyment on a par with conventional automobiles remains high even for low-fuel-consumption vehicles.

Hybrid electric vehicles (HEV) are typical low-fuel-consumption vehicles, and are equipped with traction motors, dedicated batteries and other devices in addition to internal combustion engines. The combination of these devices reduces automobile fuel consumption by increasing the combustion efficiency of the internal combustion engine and by recovering deceleration energy. In addition, acceleration performance can also be realized that makes use of motors with responsiveness and torque characteristics that differ from those of an internal combustion engine.

Honda has developed and sold HEV equipped with an Integrated Motor Assist (IMA) system classified as a parallel type. The IMA system features light weight, a compact size and low cost, and cumulative worldwide sales had reached the one million unit mark as of the end of September 2012.

In addition, the company has created a lineup of three SPORT HYBRID systems as part of its EARTH DREAMS TECHNOLOGY, which is next-generation power train technology that realizes both excellent driving performance

and high fuel efficiency. These are the one-motor SPORT HYBRID Intelligent Dual-Clutch Drive (SPORT HYBRID i-DCD), the two-motor SPORT HYBRID Intelligent Multi-Mode Drive (SPORT HYBRID i-MMD), and the three-motor SPORT HYBRID Super Handling - All Wheel Drive (SPORT HYBRID SH-AWD). The company aims to expand this lineup successively in the future in accordance with the demanded characteristics.

The IMA system used nickel metal hydride (Ni-MH) batteries since the 1999 model year Insight, but was changed to lithium-ion batteries (LIB) from the 2011 model year Civic Hybrid. LIBs feature 33% higher output and 30% lighter weight compared to Ni-MH batteries of the same voltage, which helps to further increase fuel efficiency⁽¹⁾.

IMA systems sold thus far have been designed with the engine as the main source of motive power and motors as auxiliary power sources, so the motor output was small and the battery output and capacity were also just enough to satisfy the required performance. However, the SPORT HYBRID lineup that will be expanded in the future are systems that also enable driving with only the motor, so even higher battery capacity and output will be required in the future. In addition, mountability should be enhanced by reducing the battery size to enable mounting in a wide range of models.

This development aimed to develop an LIB with a performance and size suitable for SPORT HYBRIDs that can also be mounted in a wide range of models. Furthermore, an additional goal was to realize specifications compatible with existing vehicles that use the IMA system.

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2. Development Goals

The smallest unit of a battery is called a cell, and multiple cells bundled in series are called a module. In addition, multiple modules connected in series are called a pack, with the number of modules connected in series varying in accordance with the voltage required by the system (Fig. 1).

Cell performance needs to be enhanced while maintaining the same outline dimensions and voltage characteristics in order to secure both the high performance required for SPORT HYBRIDS and compatibility with existing vehicles. Therefore, this development investigated methods of increasing the output density and capacity density, while using the same cell outline dimensions and active materials at the positive and negative electrodes as those of the previous cell.

A goal for module development was to enhance mountability by reducing its size, but the cell outline dimensions were not to be changed, so a smaller module size was realized by changing the shapes of components other than the cells.

The following three points were set as development goals when developing an LIB for SPORT HYBRID systems.

- (1) Increased cell output and capacity
- (2) Cell compatibility with existing vehicles
- (3) Reduced module size

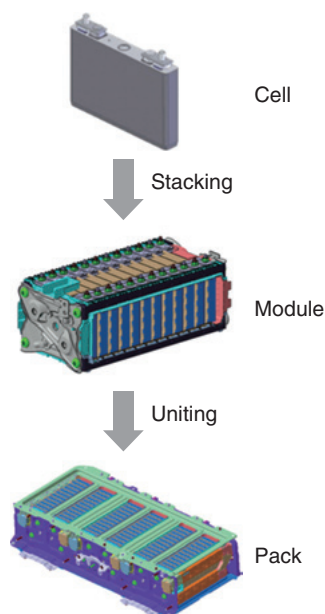


Fig. 1 Battery components for HEV

3. Cell

3.1. Cell Configuration

Figure 2 shows the structure of the cell mounted in the battery. The LIB consists of positive and negative electrodes made by coating metal foil with active materials,

current collectors that connect the positive and negative electrodes with the respective terminals, an electrolysis solution consisting of an organic solvent and an electrolyte, a separator that functions to hold the electrolysis solution and insulate the electrodes from each other, and a container that encloses the aforementioned components.

3.2. Enhanced Cell Performance

The surface area of the electrodes was expanded to achieve the development goal of increased cell output.

Output is calculated as the product of the current and the closed circuit voltage. The size of the allowable battery current I can be expressed by Eq. (1)⁽²⁾.

$$I = n F A k C_M C_E \exp(n \alpha F \eta / RT) \quad (1)$$

n : number of electrons participating in the battery reaction, F : Faraday constant, A : effective surface area of the electrode, k : reaction rate constant, C_M and C_E : Concentrations of the electrode and the substance reacting with the electrode, α : transmission coefficient, η : overpotential, R : gas constant, T : absolute temperature

Equation (1) indicates that the current flowing to the electrode increases together with the effective surface area of the electrode A , and that cell output can be increased without changing the active materials at the positive and negative electrodes.

The thickness of the substrates onto which the active materials are coated and the thickness of the separator were reduced and the electrode length was increased in order to expand the surface area of the electrode. In addition, reducing the separator thickness shortened the distance between the positive and negative electrodes, which suppressed the cell internal impedance⁽³⁾, and the use of additives to form the film on the electrode surface also helped to increase the output.

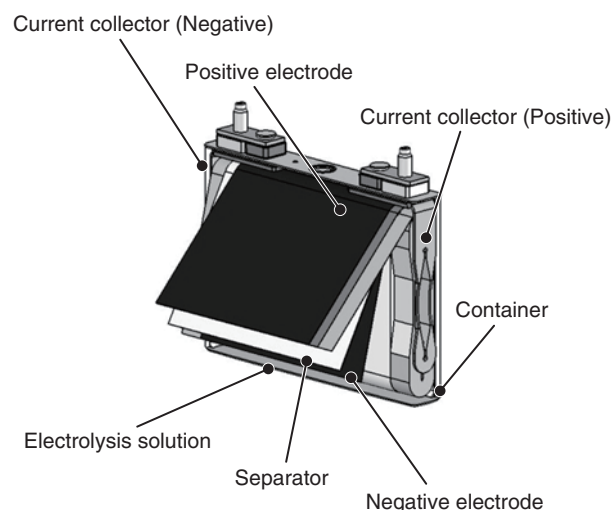


Fig. 2 Construction of cell

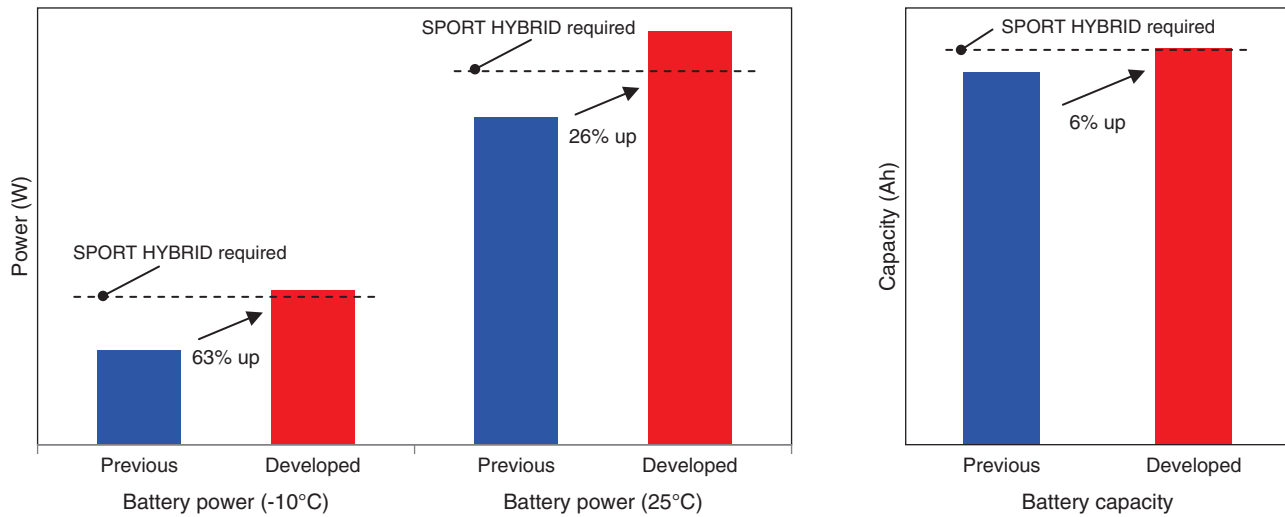


Fig. 3 Comparison of battery performance

The amount of active materials applied to the positive and negative electrodes was increased to achieve a higher cell capacity. The capacity is proportional to the amount of active materials applied⁽⁴⁾, so the positive and negative electrode substrate thickness and the separator thickness were reduced to secure space, and the amount of active materials applied to the positive and negative electrodes was increased to increase the cell capacity.

As a result of the above methods, the developed cell achieves 63% higher output at -10°C and 26% higher output and 6% higher capacity at 25°C compared to the previous cell. These enhancements enabled achievement of the required performance targets for SPORT HYBRID systems (Fig. 3).

Enhanced cell performance was achieved by expanding the surface area of the electrode and increasing the amount of active materials applied. However, the volume of the cell container and the characteristics of the active materials at the positive and negative electrodes are the same as those for the 2011 model year Civic Hybrid. This means that the cell outline dimensions and voltage characteristics are also the same as those for the 2011 model year Civic Hybrid, so cell mounting compatibility was also achieved.

4. Module

4.1. Module Configuration

Figure 4 shows the construction of the module. The module consists of cells, which are the smallest battery unit, holders that position the cells and secure insulation and cooling air channels between the cells, springs that hold the cells, end plates, and frames.

Modules require strength sufficient to withstand external stress such as oscillation of the cell and the module itself due to vibration while driving, and internal stress such as cell expansion.

4.2. Reduced Module Size

Cast magnesium end plates were used to reduce the weight of modules mounted in the 2011 model year Civic Hybrid, and each module consisted of 10 stacked cells.

The developed module assumed application to a wide range of models, and size reduction was set as a goal. In addition, the number of stacked cells was increased by two cells to 12 cells per module in order to mount the optimum quantity for SPORT HYBRID systems. This increased the stack length, which greatly increased the torsional displacement.

The frames were changed to box structures positioned on the four corners of the end plates, and a four-point cell holding structure was also used to suppress the cell torsional displacement and disperse the coupling stress between the frames and end plates (Fig. 5).

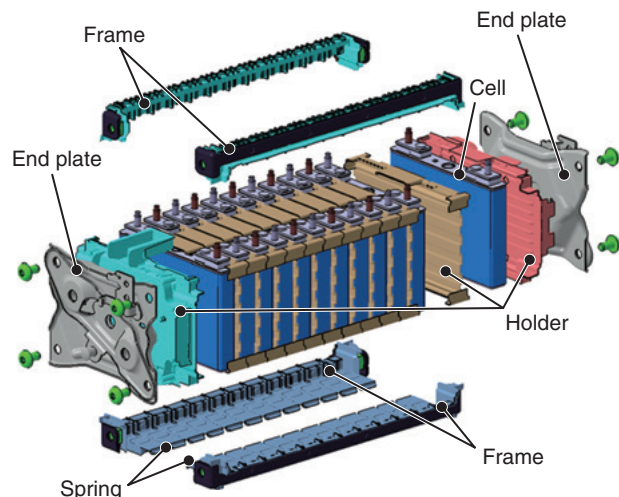


Fig. 4 Construction of module

These measures kept the maximum stress on the end plates and frames within the limits and successfully addressed the issues produced by increasing the number of cells.

The end plates were changed from cast magnesium to steel plates and the thickness was reduced in order to reduce the module size (Fig. 6). As a result, the end plate thickness could be reduced by 37%. Note that the increase in module component weight (excluding the cells) due to the change in end plate materials was offset by changing the materials and shapes of the frames and holders, and the same module component weight was achieved as that of the modules mounted in the 2011 model year Civic Hybrid.

The number of developed modules mounted can be changed in accordance with the demands of the hybrid system. Six of the developed modules are mounted in the SPORT HYBRID i-MMD 2014 model year Accord Hybrid (Fig. 7), and reducing the module size achieved a 7% reduction in length in the cell stacking direction compared to the previous structure.

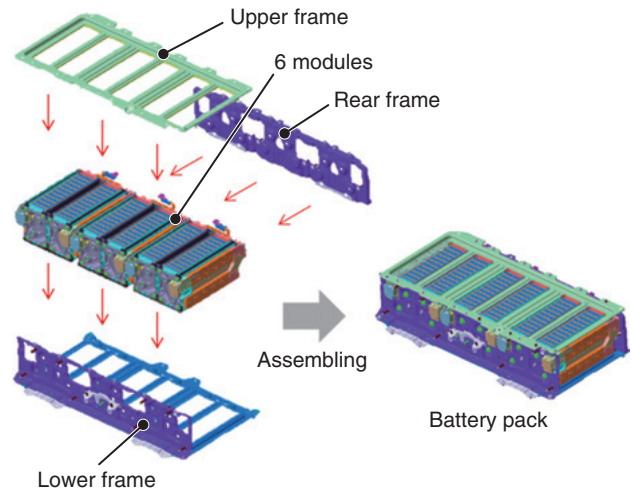


Fig. 7 Battery pack for 2014 model year Accord Hybrid

5. Conclusion

An LIB was developed for the SPORT HYBRID lineup, and the three set development goals were achieved to the following degrees.

(1) Increased cell output and capacity

The electrodes were lengthened, the surface area of the electrodes was increased, and the amount of active materials at the positive and negative electrodes was also increased. This resulted in 63% higher output at -10°C and 26% higher output and 6% higher capacity at 25°C compared to the previous cell, which achieved the performance required by SPORT HYBRID systems.

(2) Cell compatibility with existing vehicles

Cell output and capacity were increased without changing the active materials at the positive and negative electrodes, so the voltage characteristics are the same as those of existing vehicles. In addition, the cell outline dimensions were not changed, so cell compatibility with existing vehicles was achieved.

(3) Reduced module size

Changing the end plates from cast magnesium to steel plates enabled reducing the length in the cell stacking direction by 7% compared to the previous structure, and achieved a smaller module size.

The developed product is scheduled for successive adoption from the 2014 model year Accord Hybrid.

References

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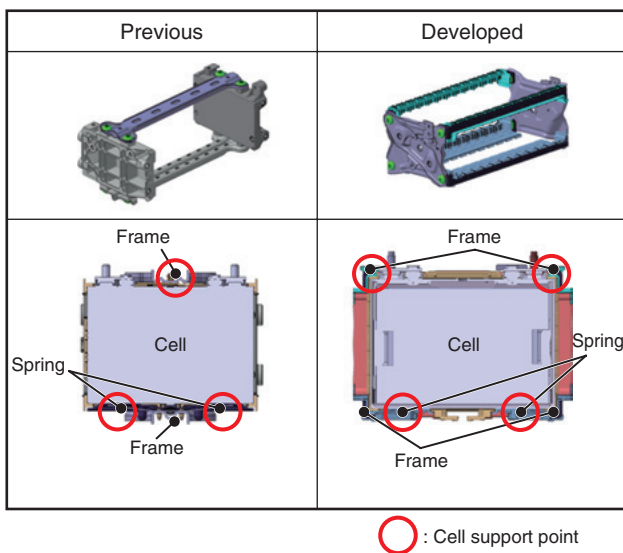


Fig. 5 Cell support points

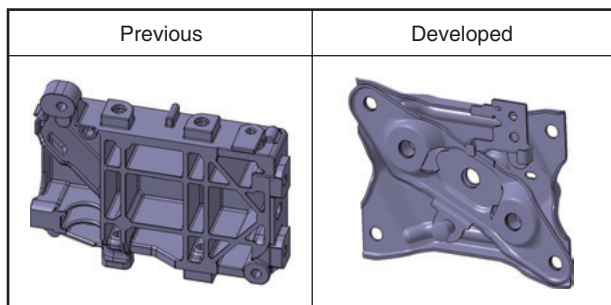


Fig. 6 Module end plate

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