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Development of New System For Cool Hybrid

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Summary

New ”PROFIA COOL Hybrid ” has been developed with the system renovation of PROFIA Hybrid. It realized coexistence of fuel economy performance and cooling performance by the optimizing control of energy management for a refrigerator truck. Furthermore, in order to meet refrigerator truck users' demand, we added a new function which drives refrigerator after engine stop. The fuel economy performance and cooling performance were verified in internal evaluation.

Keywords:heavy-duty, truck, HEV (hybrid electric vehicle), power management, battery SoC (state of charge)

1 Background

In 2014, Hino Motors, Ltd. launched a heavy duty truck with electric refrigerator, named Cool Hybrid. It is based on the concept of reducing the driving fuel of the bodywork as a new method of utilizing hybrid technology, and has been very well received.

Since the hybrid system was renewed at Profia Hybrid released in 2019, we report on the development contents and effects of the new Profia Cool Hybrid at this report.Fig. 1 shows the appearance of the new model.

Fig.1 New Profia Cool Hybrid

2. Cool Hybrid

2.1 Conventional system

The cool hybrid launched in 2014 was developed with the following development policy.

① The motor is not used for starting and driving assistance. The motor is used only for regeneration and power generation as a generator.

② Realize low cost and space saving by utilizing the hybrid unit that has been put to practical use in light duty trucks.

③ Make the most of the shape of the freezer to reduce air resistance.

It was well received in the market for its cool-down (loading compartment cooling) and fuel economy. On the other hand, the hybrid system could not be used for driving.

2.2 Development Target

Table 1 shows the main specification of Profia's hybrid system. Using this system, the development policy for the new Cool Hybrid is as follows.

① Refrigerator can be driven when the engine is stopped

② Achieve both refrigerator drive and Hybrid vehicle driving

③ Reduce cool-down time

④ Increase fuel efficiency by 10% compared to the current cool hybrid

Table.1 Main specification of Profia's hybrid system

	2019 model	New model
Engine	E13C (410ps/220kgf・m)	A09C-VM (380ps/180kgf・m)
Transmission	12-Speed AMT	←
Motor / Generator	36 kW	90 kW
HV-Battely	Nickel metal hydride battery 288V-6.5Ah（2kWh）	Lithium ion battery 276V-40Ah(11kWh)

3. Configuration of Cool Hybrid system

Fig. 2 shows the system configuration of Profia Cool Hybrid. The diesel engine, clutch, motor, and transmission are arranged on the same axis. Regarding the connection between the hybrid system and the refrigerator, the junction block (J / B) for extracting the high-voltage power supply and the communication port for control. Fig.3 shows the high voltage junction block, Fig.4 shows the connecter for the refrigerator

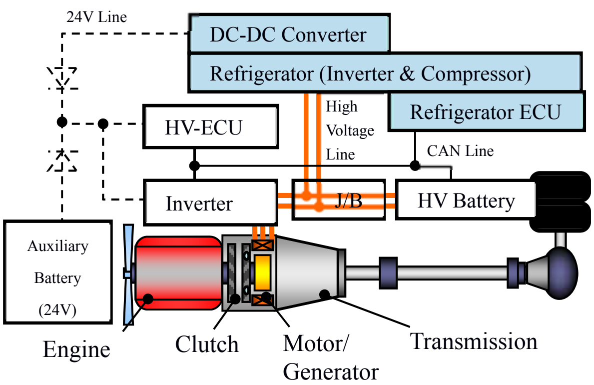

Fig.2 Cool Hybrid system

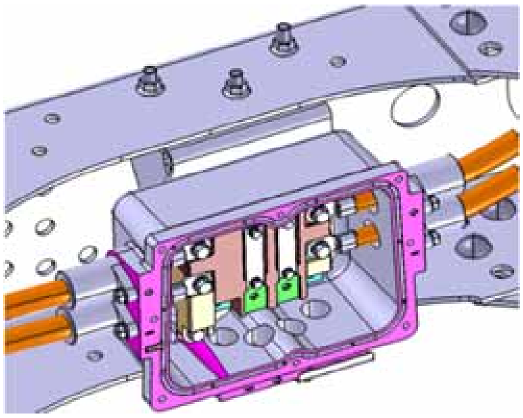

Fig.3 High voltage junction block

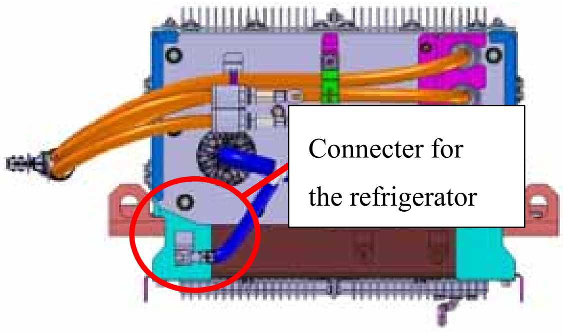

Fig.4 Connector for refrigerator
(Located before HV battery)

4. System review

In this chapter, the main functions and system specifications of the new Cool Hybrid are shown.

4.1 Refrigerator drive when engine is stopped

As a result of the customer survey, there is a high interest in reducing exhaust gas and noise for idling during the time of waiting for cargo handling and their rest time. There were many requests to drive the refrigerator with the engine stopped. Therefore, a function has been added that allows the refrigerator to continue to operate even after the engine is stopped.

In addition, the time for which the refrigerator can be kept cold while the engine is stopped was set as one hour. Regardless of the seasonal factors, the inside temperature is set to -30 degC. This function can be set on the refrigerator according to user needs.

When the refrigerator is driven with the engine stopped, the two points shown in Sections 4.1.1 to 4.1.2 are taken.

4.1.1 Securing auxiliary battery powewhen engine is stopped

In this system, the auxiliary battery (24V) is charged by an alternator that drives the engine.Therefore, when the engine is stopped, the power supply to the auxiliary battery is stopped.So, the DC-DC converter used in the refrigerator is designed to supply power to the auxiliary battery (24V) while the refrigerator is operating.

4.1.2 System monitoring and notification for refrigerator drive when engine is stopped

In order to drive the refrigerator normally with the engine stopped after the ignition key is turned off, the HV system is monitored and notified while power is being supplied from the HV system to the refrigerator.

Furthermore, since the time during which the refrigerator can be driven depends on the remaining capacity (SOC: State of charge) of the HV battery, the SOC needs to be notified to the driver.

However, after the ignition key is turned off, the SOC information displayed on the vehicle meter is turned off. In order for the vehicle meter to remain lit even after the ignition key is turned off, a significant circuit configuration change is required.

Therefore, after the ignition key is turned off, the remaining capacity of the battery and the failure information of the HV system are notified to the control panel of the refrigerator. Information necessary for the notification is communicated by a CAN circuit with the refrigerator ECU.

4.2 Energy management

In a parallel hybrid vehicle system, deceleration energy is converted into electric power by a generator and charged into an HV battery. The electric power is used as a motor driving force during acceleration and it reduces engine work. On the other hand, in the system of Cool Hybrid vehicles, as shown below, the electric power generated by the generator is mainly used to drive the electric refrigerator, and the surplus electric power is used as the motor driving force to drive the vehicle.

① Vehicle deceleration

When the vehicle decelerates, as shown in Fig. 5, the deceleration energy of the vehicle is converted into electric power by a generator, and electric power is supplied to the refrigerator. The surplus power is charged into the HV battery. When the SOC of the HV battery is equal to or higher than the specified value, the required power is supplied to the refrigerator as shown in Fig. 6, and the HV battery is not charged.

② Vehicle acceleration / stop

When accelerating or stopping, the power of the HV battery is supplied to the refrigerator as shown in Fig.7. When the SOC of the HV battery is less than or equal to the specified value, the engine power is converted by a generator, as shown in Fig. 8, and power is supplied to the refrigerator. Further, when the SOC is surplus, as shown in Fig. 9, the electric power of the HV battery is applied to the refrigerator and also supplied to the motor, and used for running the vehicle in order to improve fuel economy.

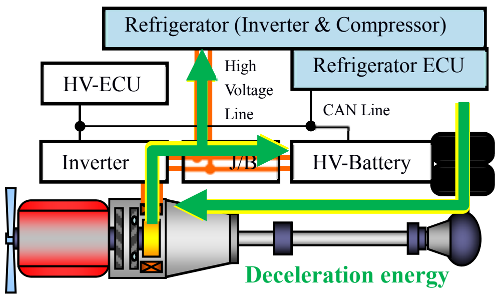

Fig.5 Flow of electric power

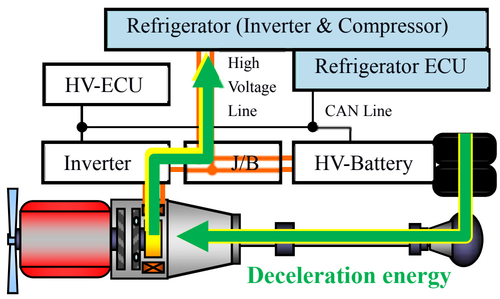

Fig.6 Flow of electric power

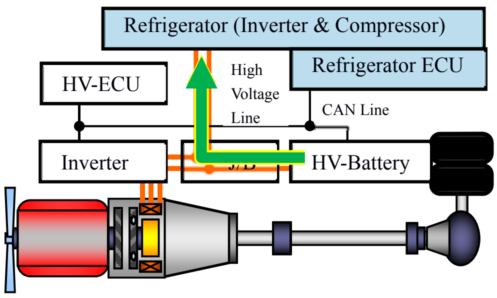

Fig.7 Flow of electric power

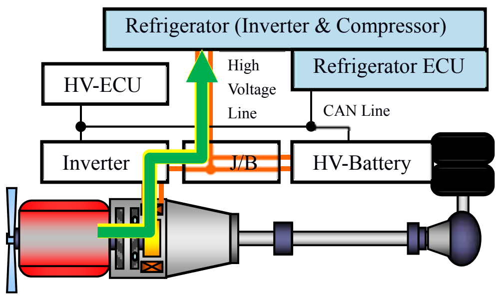

Fig.8 Flow of electric power

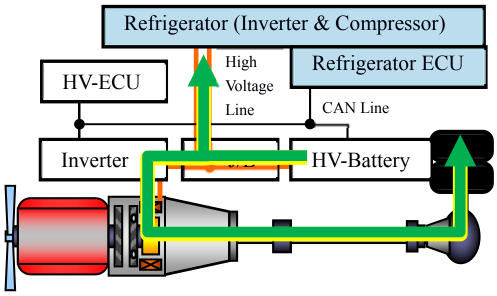

Fig.9 Flow of electric power

5. Evaluation

The new system was installed in a vehicle, and the cool-down performance, refrigerator drive performance when engine stop, and fuel economy were evaluated. The results are shown in this chapter.

5.1 Cool-down time

As an evaluation of the cooling performance of the cargo room, an evaluation was performed in a constant temperature room. Conditions are as follows;

- Outside temperature 35 degC.
- Humidity 60%.
- Give solar radiation in the hot summer.
- The refrigerator is driven until the internaltemperature reaches -20 degC.

The temperature change in the cargo room is shown in Fig.10 By changing the HV system to increase the allowable output of the refrigerator and improving the refrigerator, the cool-down time has been reduced to 65% compared to the 2014 model. It is also 87% shorter than the 2014 model minor change.

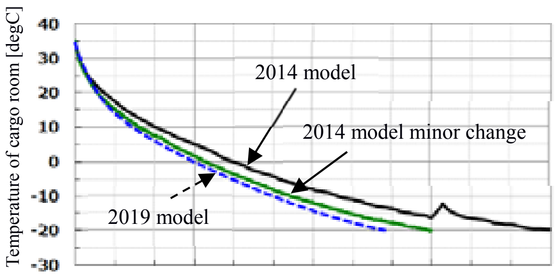

Fig.10 Cool –down time

5.2 Refrigerator drive function when engine is stopped

Fig. 11 shows the results of confirming the cold insulation performance with the engine stopped under the evaluation conditions in the previous section. By using the electric power stored in the HV battery to drive the refrigerator in accordance with the temperature rise in the cargo room, the temperature in the refrigerator was maintained at -30 degC for 1 hour.

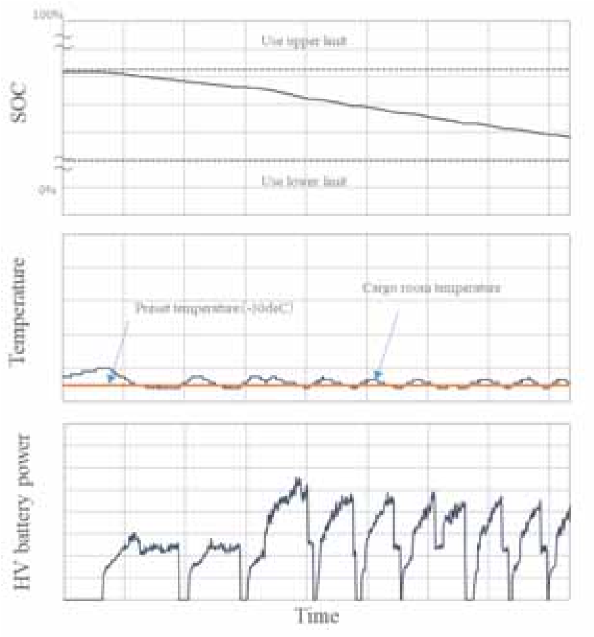

Fig.11 Cold insulation performance

5.3 Fuel economy

A running test was conducted with an internal evaluation pattern. Fig.12 shows internal evaluation pattern. Using this pattern that simulated long-distance delivery, the fuel economy was compared between the new model and the 2014 model minor change. The results are shown in Fig. 13. The average fuel economy improvement effect of 12% was confirmed. Fig.14 shows a breakdown of energy consumption. Recovering a part of the energy required for driving the refrigerator and running by regenerative power reduced engine work and improves fuel economy.

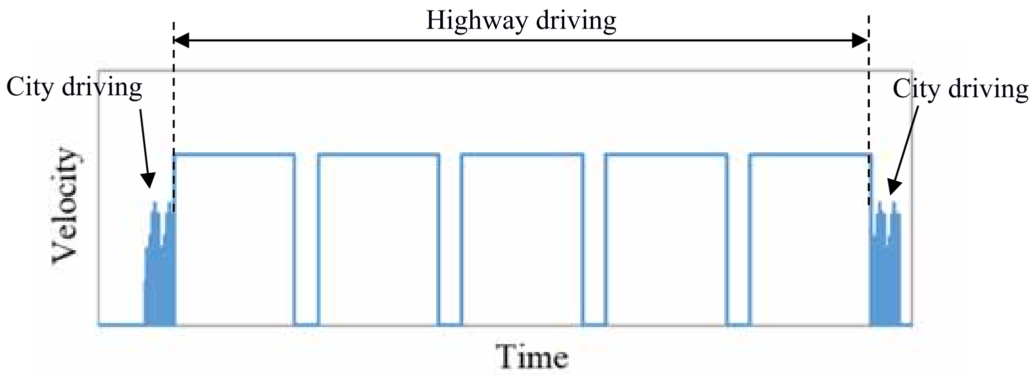

Fig.12 Internal evaluation patter

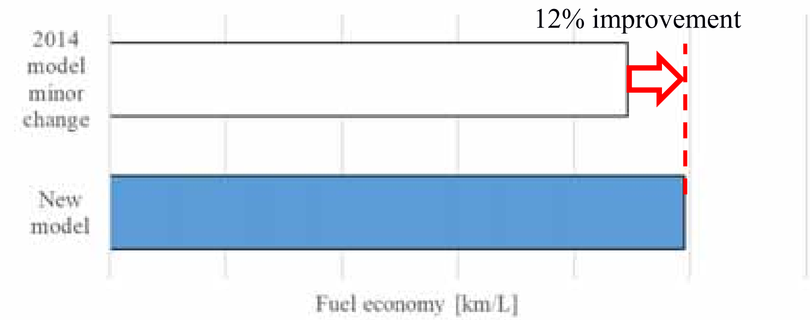

Fig.13 Results of fuel economy (Internal evaluation)

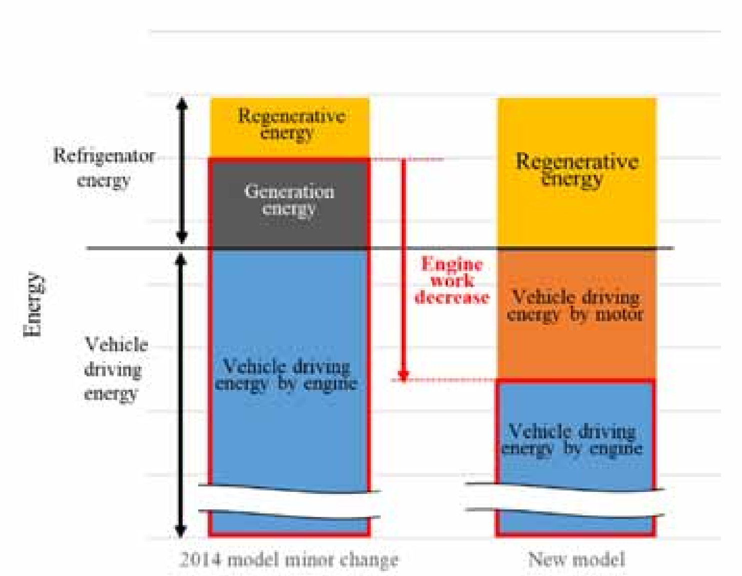

Fig.14 Breakdown of energy consumption

5.4 Market Monitor Evaluation

Fig. 15 shows a part of the driving data in the monitor evaluation. In cooperation with a private carrier, this evaluation was performed to confirm the cool-down performance and fuel efficiency in the market. Not only during running but also during a break during high-speed running, the refrigerator is continuously driven with the engine stopped, and the temperature in the refrigerator is maintained at the set temperature.

And the results of fuel economy are shown in Fig. 16. The average fuel economy improvement effect of 11% was confirmed.

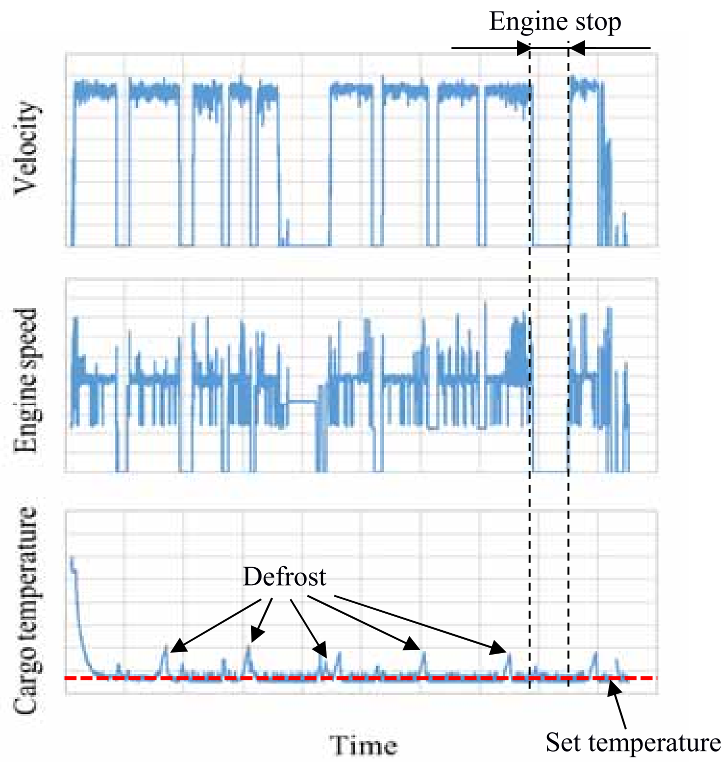

Fig.15 Temperature transition in the market monitor

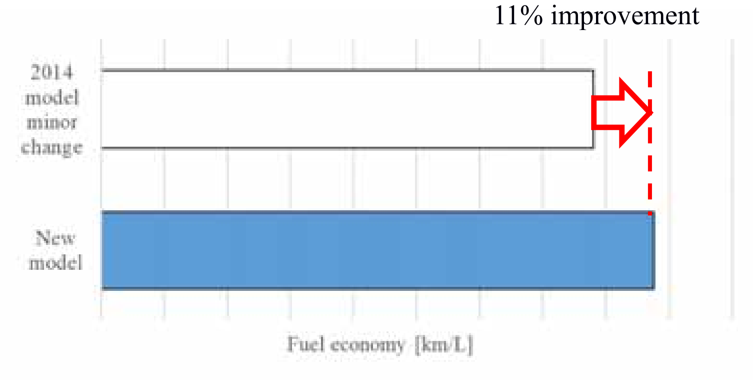

Fig.16 Result of fuel economy (Market monitor)

6. Conclusion

The new Profia Cool Hybrid with the new hybrid system has been improved. And fuel economy, refrigeration performance and noise performance has been improved.

In addition, this technology was also deployed in the light duty truck Dutro Hybrid. Cool hybrids are expected to become the mainstay of future refrigerator trucks for both heavy and light duty trucks.

Reference

[1] Y. Kawata et, *Development of Cool Hybrid,*
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