

The Development of New Hino Hybrid Commercial Vehicles

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Shigeru Suzuki
Hino Motors, Ltd

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ABSTRACT

In 1991, Hino Motors, Ltd. (Hino) launched the world's first hybrid city buses in the market. Thereafter, Hino has improved its hybrid vehicle technology and applied it to various commercial vehicles including city buses, sightseeing buses, medium-duty trucks and light-duty trucks. Recently, Hino has developed light-duty hybrid trucks, whose fuel efficiency has improved by 50% relative to its Diesel trucks. The significant improvement in fuel efficiency is achieved by four improvements in hybrid trucks. First, the hybrid system is improved: the change in the drive train layout, the relocation of a clutch, makes it possible to recoup the regenerative energy more efficiently. Second, the vehicle is also improved by the new hybrid engine, the reduction of the rotation speed of the engine during idling, and the improvement in the differential gear ratio. Third, new hybrid system controls are developed to bring benefits of the hybrid system to all drivers. Forth, low-cost but efficient units are developed to make fuel efficient hybrid vehicles prevail in the market. This paper discusses new Hino hybrid vehicle technologies developed for the light-duty trucks.

INTRODUCTION

Global warming and climate change accompanied by natural disasters all over the world are one of the most important concerns in the world. To fight against global warming, both developed and developing countries try hard to reduce Carbon Dioxide (CO₂) emissions. Among all CO₂ emitters, automobiles, more specifically, commercial vehicles constitute a large portion of CO₂ emissions. Therefore, reducing CO₂ emissions through fuel efficiency improvements becomes increasingly important because it reduces not only costs but also environmental burden.

Under such circumstances, Hino started manufacturing the world's first light-duty hybrid trucks in 2003 and improved its quality even further in 2006. Facing a recent downward trend in CO₂ emissions from freight transportation (ship and automobile), Hino believes that it has played a part in the achievement. However, reducing CO₂ emissions is an endless battle: fuel efficiency should be improved even more and fuel efficient vehicles should prevail all over the world.

In July 2011, equipped with a new system and new units, new light-duty hybrid trucks, which achieve both fuel efficiency improvement and cost reduction was released by Hino (see [Figure 1.1](#) and [1.2](#)). The new light-duty hybrid trucks have been developed as a global model: it targets not only the Japanese market but also other markets around the world.

This paper discusses technology and improvements embodied in the new hybrid system and new vehicle.



Figure 1.1. New Hybrid Vehicles



Figure 1.1. New Hybrid Vehicles (cont'd)



Figure 1.2. New Hybrid System

1. GOALS AND STRATEGIES

1.1. GOALS

- (1). Fuel efficiency improvement (50% or more improvement relative to diesel trucks.)
- (2). Cost reduction (the cost of the new hybrid system is cut by half relative to the present Hino system.)
- (3). Compliance with applicable regulations and laws including the new safety standards.

1.2. BASIC STRATEGIES

To improve fuel efficiency, two major changes are made in the new hybrid trucks. First, the hybrid system is changed. In the new hybrid system the clutch is set between an engine and a motor to recoup the regenerative energy more efficiently, while an engine and a motor are directly linked in the present Hino hybrid system. In addition, the new hybrid trucks adopt an Automated Manual Transmission (AMT),

which changes the speed automatically without a clutch pedal. With the AMT, all drivers receive benefits of the hybrid system without sacrifice of driving simplicity.

2. VEHICLE SPECIFICATIONS AND THE BASIC SYSTEM

2.1. VEHICLE SPECIFICATIONS

Table 2.1. Vehicle Specifications

	Present Model	New Model (Japanese model)
Engine Model	N04C-UJ	N04C-UL
Style	4-cylinder inline	4-cylinder inline
Engine Displacement	4.009 L	4.009 L
Fuel Feed System	Common Rail Direct Injection	Common Rail Direct Injection
Fuel	Diesel	Diesel
Maximum Power	100 kW /2500 rpm	110 kW /2500 rpm
Max Torque	392 Nm /1600 rpm	420 Nm /1400 rpm
Transmission	MT(5 gears, 6 gears)	AMT (5 gears)
Max Loading Capacity	2t – 3t	2t – 4t

2.2. BASIC SYSTEM

Figure 2.1 shows the basic system of the new hybrid truck. The new hybrid truck uses the parallel hybrid system: Diesel engine, clutch, motor, and AMT are arranged on the same axle. A Power Control Unit (PCU) is installed on the chassis frame, and a battery, an inverter and an ECU are set inside the PCU.

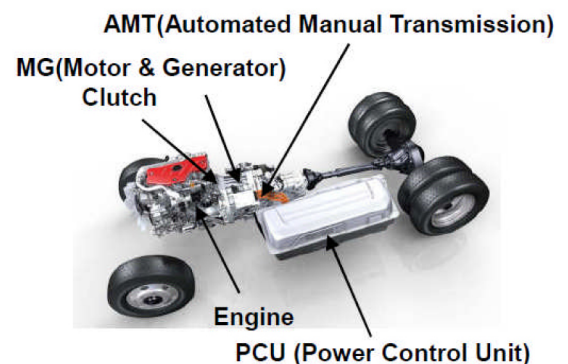


Figure 2.1. The Basic System of the New Model

3. NEW HYBRID SYSTEM

To improve fuel efficiency by at least 50%, three major changes are made in the new hybrid trucks. First, the drive train layout is changed to recoup the regenerative energy

more efficiently. Second, the vehicle itself is modified to improve fuel efficiency more. Last, hybrid control systems are developed to bring benefit of the hybrid system to all drivers. This section discusses each change in turn.

3.1. THE DRIVE TRAIN LAYOUT

The parallel hybrid vehicle system has three principal functions. (1) Regenerative brake, which recoups some of the energy lost during stopping and reuses it. (2) Low dependence on an engine during low-speed driving (Instead of an inefficient engine, a motor is used during low-speed driving.) (3) Idle stop.

To utilize the former two functions more, the layout of the drive train is changed: the key is to change the position of a motor and a clutch.

Figure 3.1 and Figure 3.2 show the present Hino hybrid vehicle and the new Hino hybrid vehicle respectively. Since the engine and the motor are directly linked, the regenerative brake system cannot recoup the pumping loss, and the motor and the engine are forced to work together all the time. In contrast, a clutch between the engine and the motor in the new model, helps the regenerative brake system to recoup more energy during deceleration and enables the motor to work alone during acceleration by disconnecting the engine.

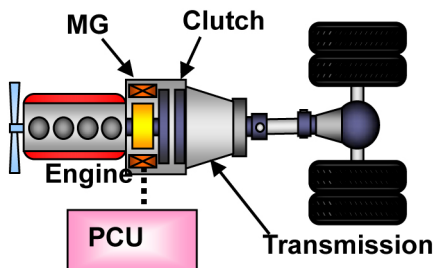


Figure 3.1. Present Hino Model

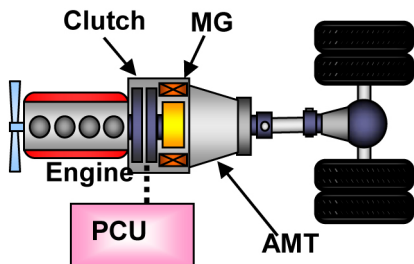


Figure 3.2. New Hino Model

To deliver full benefit of the above-mentioned hybrid system, Automated Manual Transmission (AMT), transmits the engine power effectively and help all drivers to drive fuel efficiently, is adopted in the new hybrid vehicle. As shown in Figure 3.3, in starting the engine, the clutch is engaged, and

both engine and motor drive the vehicle. In starting the vehicle, the engine is automatically switched on or off depending on the remaining quantity of the battery. If the remaining quantity of the battery is high enough, the clutch is disengaged and the vehicle is operated with motor alone. (Motor start) On the contrary, both a motor and an engine work together if the battery is not high and the clutch is engaged. (Engine-assisted Start) During acceleration, the engine powers the vehicle with the assistance of the motor. (the torque-assist mechanism, which is also used in the present Hino model) During deceleration, the regenerative brake system works: the clutch is disengaged, the kinetic energy of the vehicle is converted into electricity, and electricity is stored into the battery for later use.

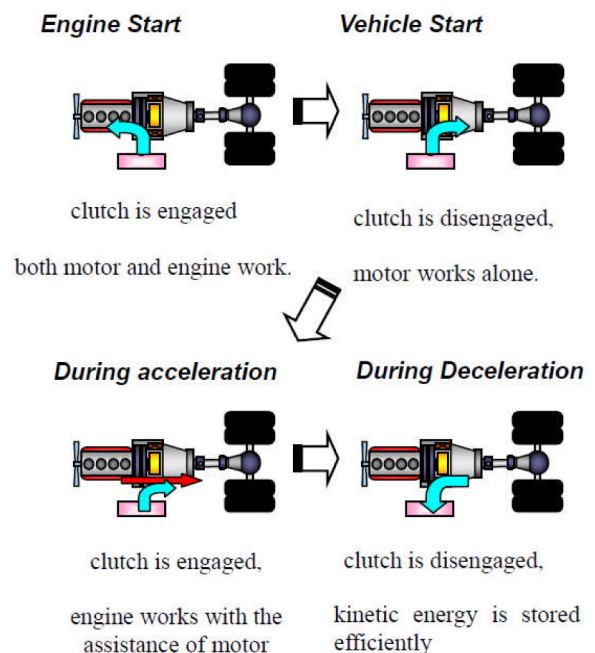


Figure 3.3. New Hybrid System

3.2. EVALUATION: THE NEW DRIVE TRAIN LAYOUT

Figure 3.4 shows the fuel consumption of a Hino Diesel vehicle (base vehicle), a present hybrid truck, and a new hybrid truck at the average speed of 28 km/h. (the speed of delivery vehicle in the suburban area) As mentioned before, the goal is to improve the fuel efficiency by 50%, which is equivalent to the fuel consumption of 368 cc and the fuel consumption reduction rate of 33.3 %. Point A and Point B in Figure 3.4 show the fuel consumption and the regenerated energy of the present model and those of the new model respectively. Compared the new hybrid vehicle with the present hybrid one, the change in drive train increase the regenerated energy by 37% (see Table 5.1). The combined effect of the increase in the regenerated energy and the motor driving reduces the fuel consumption of the new hybrid