

Development of New Hybrid Transmission for Compact-Class Vehicles

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1. ABSTRACT

A new hybrid transmission has been developed for New compact class vehicles. The development of this transmission has been aimed at improving fuel economy and achieving the weight reduction and compact size. In order to achieve these goals, the gear train and motor have been newly designed and advanced technology applied. This paper describes the major features and performance of this transmission in detail.

2. INTRODUCTION

In recent years, due to mounting concerns regarding the environment and energy conservation, it has become ever more important to reduce CO₂ emissions from automobiles and improve fuel efficiency. The hybrid vehicle technology that combines an engine with a motor/generator has been an important development toward improving vehicle fuel efficiency.

In December 1997, the world's first mass-production hybrid system was developed and installed in a compact-class vehicle. Since then, many improvements have been made to the hybrid system, and in September 2003, a new transmission (P112) was developed as part of a second-generation hybrid system for installation in compact-class vehicles. Then in 2005, a hybrid transmission (P310) having a new motor speed reduction device was developed for use in SUVs. Now, a new hybrid transmission (P410) has been developed that adapts the P310 and its structure to compact-class

vehicles, which require a compact size, light weight, and low fuel consumption.

This paper describes the structural characteristics, the compact high-output motor, and other features of this new hybrid transmission (P410).

3. DEVELOPMENT OBJECTIVES

The development objectives of the new hybrid transmission for compact-class vehicles were size/weight reduction, fuel efficiency improvement, quiet operation, and powertrain performance improvement.

(1) Size/weight reduction

When the engine and motor outputs were increased, it was necessary to simultaneously achieve capacity increase and size reduction with respect to the earlier hybrid transmission (P112) used in compact-class vehicles, in order to ensure installability. To achieve size and weight reductions, the motor speed reduction device and compact high-output motor utilized in SUVs were adopted.

(2) Fuel efficiency improvement

To achieve a top-class fuel efficiency level, the loss inside the motor was reduced and other loss-reduction measures were implemented, such as optimizing lubrication inside the transmission and eliminating chains.

(3) Quiet operation

To achieve quiet operation in new compact-class vehicles, a transmission structure was developed that disperses the resonance points of the components, and also adopted a new method of manufacturing the gear teeth.

(4) Powertrain performance improvement

To improve the powertrain performance of the new hybrid transmission for compact vehicles, the motor output was increased by raising the speed and voltage of both the motor and the generator.

4. BASIC SPECIFICATIONS AND STRUCTURE

Figure 1 shows the main cross section of the new hybrid transmission (P410), and Table 1 details the main specifications.

Unlike the older P112, the P410 uses a motor speed reduction device and a compound gear, resulting in a totally different configuration. The motor speed reduction device, newly adopted for compact vehicles, increases the output of the motor while shortening its overall length.

Furthermore, providing a compound gear that integrates two planetary gears, a counter drive gear, and a parking gear, on the outside of the motor speed reduction device and the power split device eliminates the need for the chain required in conventional hybrid transmissions, and reduces the number of axis from four to three, achieving a compact size.

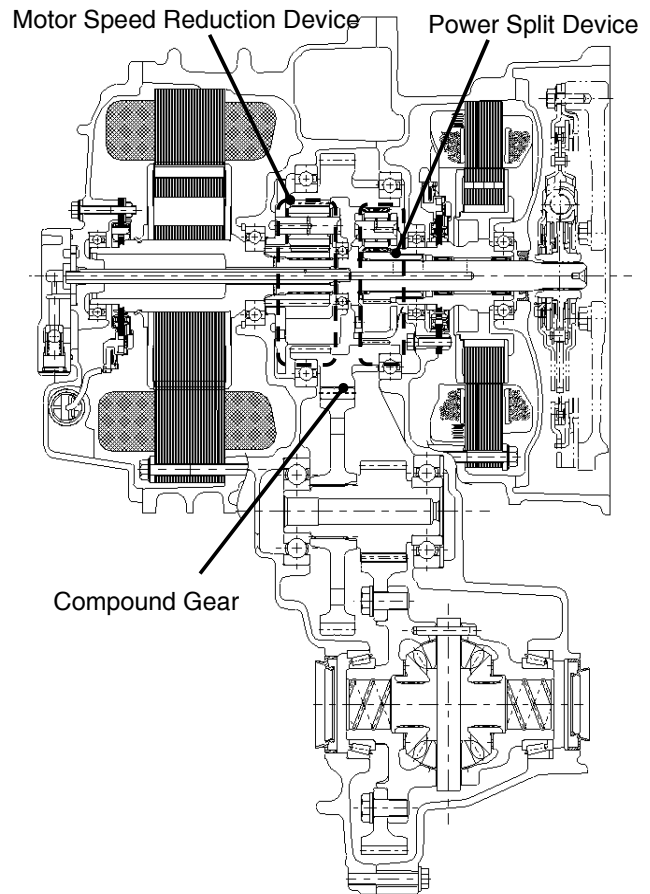


Fig. 1 P410 Cross Section

Table1 Specifications of New Hybrid Transmission

		P410	P112
Max. Engine Torque		142 Nm	115 Nm
Max. Engine Output		73 KW	57 kW
Motor	Type	Synchronous AC motor	←
	Max. Output	60 kW	50kW
	Max. Torque	207 Nm	400 Nm
	Max. Speed	13500 rpm	6400 rpm
Motor Reduction Gear Ratio		2.636	—
Differential Gear Ratio		3.267	4.113
Weight (Including ATF)		88kg	109kg
Overall Length		372 mm	385 mm

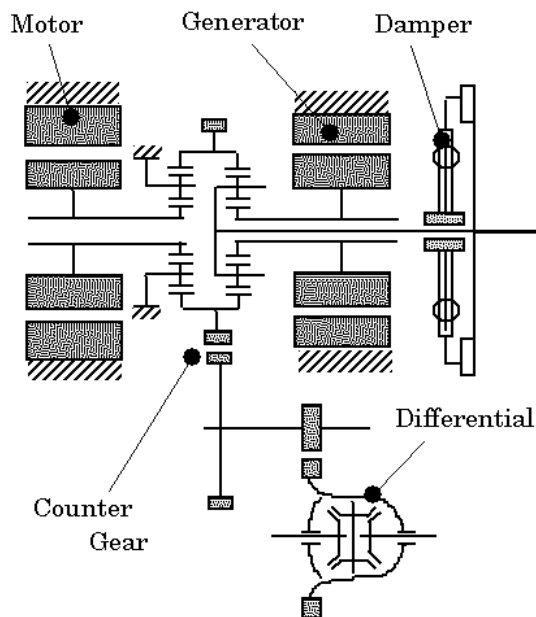


Fig. 2 Schematic of New Hybrid Transmission

Figure 2 shows a schematic diagram of the main cross section. Starting on the right side of the figure (the engine side), a two-stage hysteresis damper with a torque limiter, a generator, two planetary gears, and a motor are provided on the first axis.

The planetary gear on the right side functions as a power split device that splits the power from the engine into a motive force for the vehicle and a force for driving the generator. The planetary gear on the left side functions as a motor speed reduction device (deceleration device). A compound gear that integrates two ring gears, a counter drive gear, and a parking gear, is provided on the outside of the two planetary gears. It transmits the driving force to the counter driven gear and the drive pinion gear on the second axis, and to the ring gear and the differential on the third axis.

5. SIZE AND WEIGHT REDUCTION

At the same time that a 20% increase in the engine and motor outputs was achieved, the overall length and weight of the P410 were reduced by 10 mm and 20%, respectively, compared to the P112. This was accomplished through various steps, including the use of the motor speed reduction device and the compound gear, as well as a motor size reduction achieved through speed and voltage increases, a stator coil end size reduction, and the use of a high-energy stacked magnet.

5.1 MOTOR SPEED REDUCTION DEVICE

Figure 3 shows the structure of the adopted motor speed reduction device. The planetary gear on the left side functions as the motor speed reduction device. The sun gear of the planetary gear system is connected to the rotor of the motor by spline engagement, the carrier is fitted and fixed to the case by spline engagement, and the ring gear is integrated as part of the compound gear. This planetary gear reduces the motor's speed before transmitting it as a motive force to the counter gear and the differential.

Regarding the number of teeth on the individual gears of the motor speed reduction device, the sun gear has 22 teeth, the pinion gear has 18 teeth, and the ring gear has 58 teeth. The gear ratio is set to 2.636. The ring gear (compound gear) reduces the motor speed to $1/2.636$ while amplifying the motor torque by 2.636 times.

Thanks to the action of this motor speed reduction device, the speed of the motor can be increased while the torque is reduced, as shown in Fig. 4. Since motor size is proportional to motor torque, the motor speed reduction device allows the motor size to be reduced.

Specifically, the combined mass of the motor and the generator was reduced by 35%, the combined volume by 40%, and the combined overall length by 30%.

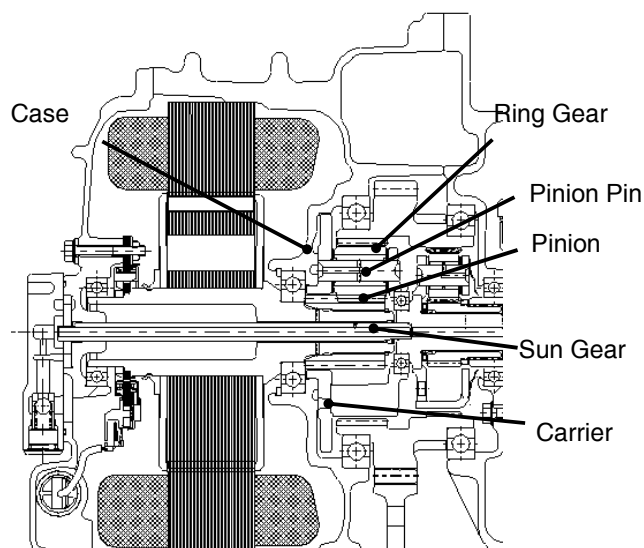


Fig. 3 Structure of Motor and Motor Speed Reduction Device