# DRIVETRAIN

## 1 Introduction

New vehicle sales in Japan (including mini-vehicles)[1] in 2019 dropped by 1.5% compared to 2018. This was the second year-on-year decrease in vehicle registrations, and the first decrease in mini-vehicle sales for three years. Although the automobile tax on registered vehicles has been reduced, these sales results probably reflect the effects of the hike in the consumption tax rate to 10%, which occurred in October. In addition, lower demand outside Japan, particularly in the U.S. and China, is also likely to result in a fall in global sales.

Wide-ranging research and technological development for the electrification of powertrains has made rapid progress in recent years as part of efforts to comply with environmental regulations and the like. As part of this trend, technological development to restrict the increases in cost and weight that accompany electrification is becoming an increasingly important part of product commercialization, in addition to simultaneous efforts to improve energy consumption efficiency. At the same time, technology to increase the efficiency of transmissions for conventional internal combustion engines is being developed with the objective of further improving vehicle fuel economy. This is also being accomplished by the development of technology to enhance user convenience through better driving performance. As a result, during this transition period toward electrification, the development of new electrified technologies is occurring simultaneously with the improvement of conventional technologies.

This article summarizes the latest power transmission systems released in the automotive industry in 2019, and also introduces the technological trends related to next-generation power transmission systems.

## 2 Automatic Transmission (AT) Trends

### 2. 1. ZF 8HP automatic transmission[2]

ZF has launched its updated third-generation 8-speed AT. It retains the existing configuration with four gear sets and five multi-plate clutches and brakes, but expands the ratio coverage to 8.6 (Fig. 1). This transmission helps to improve vehicle fuel efficiency by 2.5% compared to the second-generation AT by reducing clutch pack brake drag torque and oil pump loss, and by adopting a newly developed torsion damper.

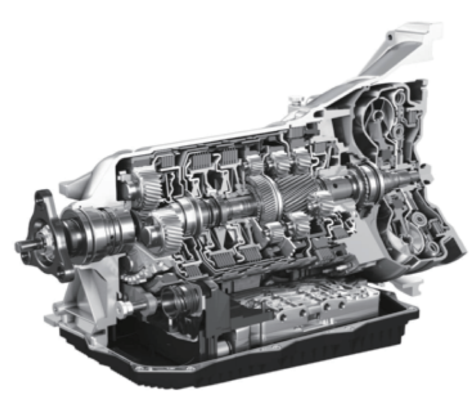

**Fig. 1** ZF 8HP Automatic Transmission

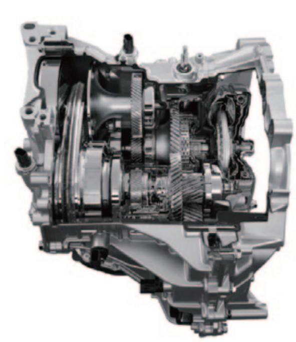

**Fig. 2** D-CVT for the Daihatsu Tanto[3]

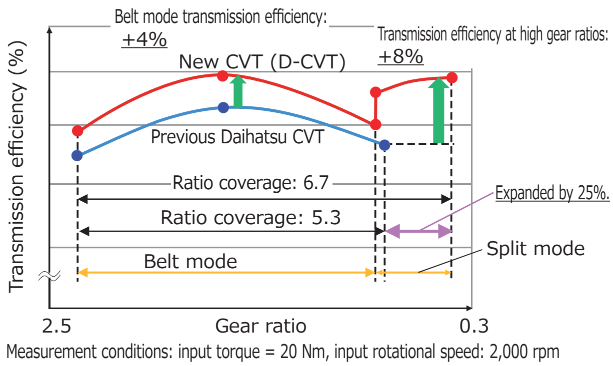


**Fig. 3** Transmission Efficiency[3]

## 3 Continuously Variable Transmission (CVT) Trends

### 3. 1. D-CVT for the Daihatsu Tanto[3]

The Tanto that was launched in July 2019 is built on a new platform that incorporates a continuously variable transmission (CVT) developed to enhance both vehicle fuel efficiency and dynamic performance (Fig. 2). In addition to the conventional belt, this CVT features a split gear. In addition to a belt mode that features belt-only drive, a split mode has been added that enables drive using both the belt and gear. This configuration improves transmission efficiency by approximately 8% in the high gear range, expands the ratio coverage compared to the previous CVT from 5.3 to 6.7, and boosts maximum acceleration from a standing start by approximately 15%.

This CVT also incorporates input reduction to lower the circumferential belt speed and reduce excess thrust caused by centrifugal hydraulic pressure. This also helps to enhance belt friction loss. Furthermore, a compact oil pump was adopted to lower oil pump loss. These loss-reduction measures help to improve transmission efficiency by approximately 4% in belt mode compared to the previous CVT (Fig. 3).

### 3. 2. CVT for the Nissan Dayz[4]

The CVT adopted on the Dayz that was launched in March 2019 was newly developed by Jatco Ltd. and Nissan specifically for mini-vehicles. The ratio coverage and basic structure of the CVT were revised to reduce size and weight for adoption on mini-vehicles, as well as to help improve vehicle fuel efficiency. The ratio coverage was changed compared to the previous CVT from 7.3 to 6.0. Then, by adopting a highly durable and efficient belt, a tighter belt diameter was realized. This enabled the auxiliary transmission to be eliminated and a shift device

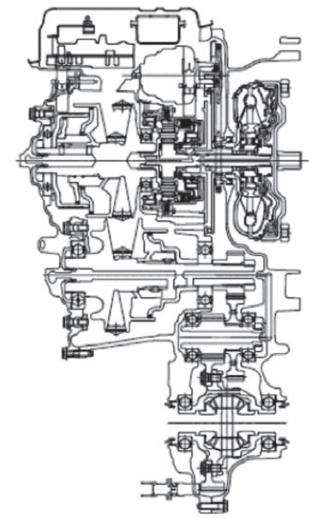

**Fig. 4** CVT for Nissan Dayz

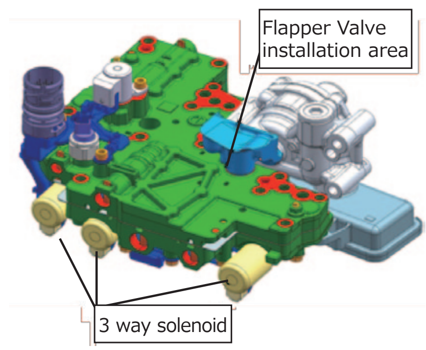


**Fig. 5** Hydraulic System Layout

featuring only a variator to be adopted (Fig. 4). As a result of these dedicated design measures for mini-vehicles, the weight of the CVT was reduced by approximately 4.2 kg, and the distance from the center of the engine was shortened by approximately 7 mm in the vehicular longitudinal direction.

Vehicle fuel efficiency was improved by approximately 6% in the JC08 test cycle by further enhancing the belt efficiency, reducing inertia by adopting a tandem structure for the primary pulley piston, adopting low-friction ball bearings in the shaft supports, and lowering agitation loss by optimizing the shape of the baffle plate. In addition, the adoption of low-leakage sealing rings and flapper valves in the hydraulic circuit helped to reduce the amount of oil dripping inside the hydraulic chamber. As a result, it was possible to install a stop-start system that also functions during coasting without adding an electrical oil pump.

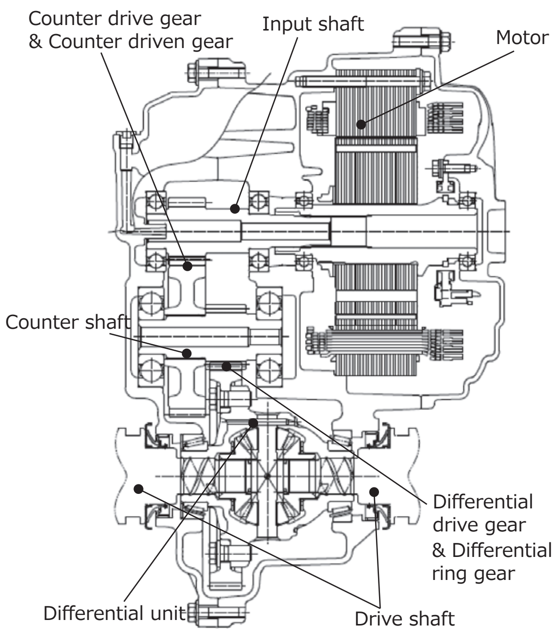


**Fig. 6** Rear Transaxle for Toyota RAV4 Hybrid(5)

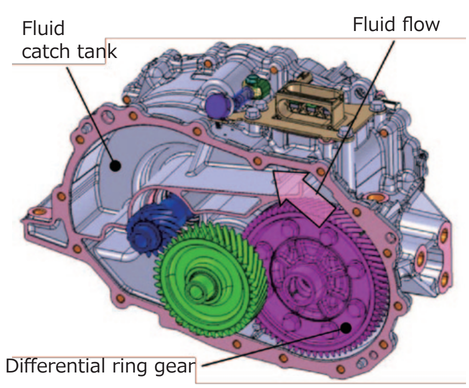


**Fig. 7** Oil Flow Concept(5)

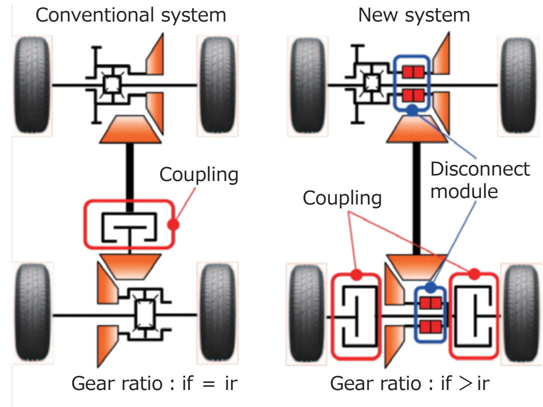


**Fig. 8** New 4WD System for the Toyota RAV4(6)

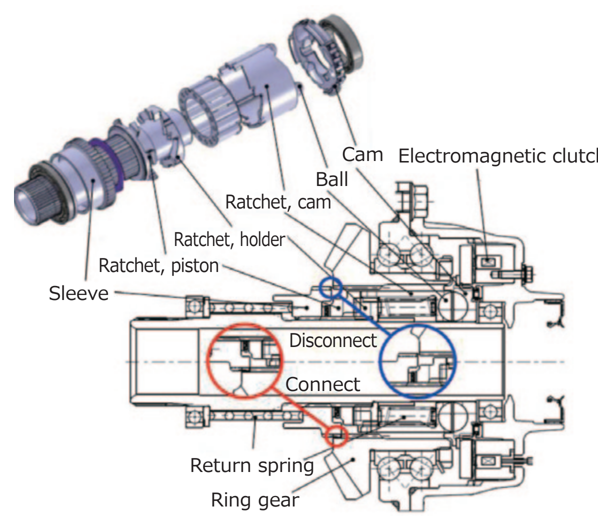


**Fig. 9** Disconnection Switching Module(6)

## 4 Drive Systems for Hybrid Vehicles

### 4. 1. Rear Transaxle for Toyota RAV4 Hybrid(5)

The new rear transaxle for the RAV4 Hybrid that was launched in April 2019 was designed to realize the traction performance required by a four-wheel drive (4WD) SUV, lower the weight and center of gravity of the vehicle, and to help improve vehicle fuel efficiency by reducing rear transaxle loss. The speed reduction device of the rear transaxle features two gear sets and three shafts (Fig. 6). Compared to the previous transaxle, the counter gear ratio was increased from 1.739 to 2.733, thereby allowing greater speed reduction. As a result, although maximum motor output was reduced from 50 to 40 kW and maximum torque from 139 to 121 Nm, the maximum rotational speed of the motor was increased from 10,500 to 17,000 rpm. These specification revisions and new development items helped to reduce the size of the motor while also ensuring driving performance. Motor size was reduced by lowering the height of the unit by 12 mm. Mass was reduced by 3%. Furthermore, the torque delivered to the tires was increased by at least 35%, thereby helping to realize the targeted traction performance.

Loss reduction was achieved by revising the geometry of the catch tank that collects the oil thrown up by the differential gear. This helps to cool the motor at low rotational speeds while also reducing agitation loss at high rotational speeds (Fig. 7). In addition, measures such as adopting distributed winding for the motor segment coil and optimizing the magnet configuration helped to reduce the loss under no load by 21% compared to the previous transaxle.

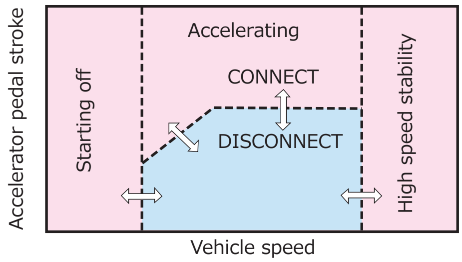


**Fig. 10** Disconnection Switching Concept[6]

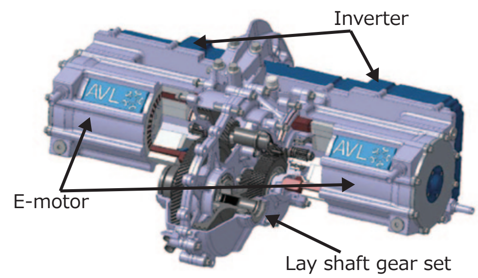


**Fig. 11** AVL Electric Drive Unit[7]

## 5 4WD Device Trends

### 5. 1. New 4WD System for the Toyota RAV4[6]

A new 4WD system was developed for the redesigned RAV4 with the aim of achieving an excellent balance between driving performance and fuel efficiency, which are generally regarded as having a trade-off relationship. The new 4WD system consists of a disconnection mechanism that contributes to fuel efficiency, and twin coupling mechanisms that contribute to driving performance (Fig. 8). To minimize drag resistance and agitation resistance, the disconnection mechanism features a function that stops propeller shaft and internal unit gear rotation when this rotation is not required. Engagement and disengagement of the dog teeth provided in the transfer and rear units is carried out by a ratchet-shift type disconnection switching module that combines an electromagnetic clutch, cams, and ratchets (Fig. 9). In addition, the switching module of the rear unit contains a propeller shaft rotation synchronizer. The twin coupling mechanisms allowed the elimination of the rear unit differential case, and enable torque distribution to the left and right rear wheels by locating couplings on the left and right sides. Furthermore, to assist moment during cornering, the gear ratio of the transfer unit was set approximately 2.5% higher than the rear unit.

To ensure both fuel efficiency and driving performance, the disconnection mechanism control connects the mechanism when the vehicle moves off and disconnects the mechanism in steady-state driving. Then, disconnection/connection is carried out depending on the road surface conditions or by driver operation, before the mechanism is connected as the vehicle stops (Fig. 10). The twin coupling mechanism control calculates the moment to apply to the vehicle based on driving information such as accelerator, brake, steering wheel, and shift operations, and vehicle state information such as wheel rotational speed, vehicle body acceleration, and yaw rate. This calculation is model-based and consists of model-following control, which creates feedforward behavior with respect to steering information, and sliding feedback control with respect to yaw rate information.

This 4WD system reduces loss by approximately 75% in 2WD mode compared to the previous system. It improves both line-tracing performance while cornering and vehicle stability, thereby achieving the development aims.

## 6 Drivetrain Mechanism Research Trends

With research and development into powertrain electrification making progress, reducing the size, weight, and cost of motors have become important issues. There are two technological approaches for reducing motor size while maintaining the maximum driving force and vehicle speed required for adequate driving performance.

The first approach is to adopt a transaxle that restricts maximum torque and combines a motor with a higher rotational speed and a reduction gear with a higher speed reduction gear ratio. AVL has presented a unit that features maximum torque of 160 Nm × 2, a maximum motor rotational speed of 30,000 rpm, and a speed reduction gear ratio of 16.7 (Fig. 11)[7].

The second approach is to adopt a transaxle that combines a motor that restricts both the maximum torque and maximum rotational speed with a multi-speed transmission. Robert Bosch GmbH has described the effectiveness of this approach for reducing motor size and energy consumption in combination with a CVT[8]. In addition, Ricardo has described its research efforts to achieve substantial cost savings by lowering maximum motor torque in combination with a 3-speed dual-clutch transmission (DCT), and to lower battery capacity by boosting energy efficiency[9].

Therefore, as described above, powertrain electrification is not just a matter of simply increasing the efficiency of the power transmission system. Other fascinating aspects include how companies are also focusing on the effectiveness of shifting functions within the powertrain system, and the increasing importance of basic technologies to address durability, noise, and vibration as motor rotational speeds increase. The role of engineers involved in power transmission systems is likely to continue becoming more and more important as the sustainable society and mobility of the future approaches.

References


・CTI Symposium 2019, "Innovative and integrated multi-speed EDU"