Drivetrain

1 Introduction

In 2013, 5.38 million vehicles were sold in Japan, roughly the same as the previous year (100.1%). The growing proportion of mini-vehicles and hybrid vehicles (HEVs) in these sales indicates the increasing importance of fuel economy for customers in Japan.

The drivetrain plays a vital role in improving the fuel economy of the vehicle. Technological development is advancing and various new drivetrain products have been launched. One of the main recent technological trends has been the development of automatic transmissions (ATs) with larger numbers of shift speeds. Both vertically and laterally mounted 9-speed ATs have now been launched onto the market.

Trends for continuously variable transmissions (CVTs) include their adoption in a wider range of mini-vehicles. Conventionally sized vehicles are adopting CVTs with wider ratio coverages and more CVTs are being adopted for vehicles sold in markets outside Japan.

In the case of HEVs, automakers are broadening their lineups and launching various types of drive systems.

2 Manual Transmission (MT) Trends

2. 1. Adoption of 7-speed MT in Chevrolet Corvette

General Motors (GM) has adopted a newly developed Tremec 7-speed MT in the Chevrolet Corvette. This MT uses multi-cone synchronizers for each forward speed to ensure smooth synchronization. It also incorporates active rev-matching technology that ensures the optimum engine speed on upshifts and downshifts.

2. 2. Adoption of 5-speed MT in Suzuki Carry

Suzuki newly developed a 5-speed MT for four-wheel drive (4WD) vehicles with an auxiliary transmission. Adopted on the Carry, this transmission has a longer distance between axes than the previous transmission (60 mm compared to 55 mm) for improved reliability. In contrast, the overall length was shortened by integrating the structure of the transmission and transfer unit.

3 Automatic Transmission Trends

3. 1. Wider adoption of 8-speed AT on Lexus models

Toyota Motor Corporation has adopted its 8-speed AT on the Lexus IS350 and GS350. This transmission achieves smooth acceleration typical of a multi-speed AT with a direct shift feeling in manual mode that takes a minimum of 0.2 seconds to make each shift.

3. 2. Adoption of 8-speed AT on Volvo XC60

The Volvo XC60 has adopted an 8-speed AT manufactured by Aisin AW. Featuring a wide ratio coverage (7.8) and centrifugal pendulum vibration absorber (only available on the D5 engine for Europe), this AT reduces the engine speed, resulting in lower fuel consumption and noise. It also features a compact and lightweight electromagnetic hydraulic pressure controller for use with an idling stop mechanism.

3. 3. Adoption of 9-speed AT in Mercedes Benz E350 BlueTEC

Mercedes Benz has adopted a newly developed 9-speed AT in the E350 BlueTEC (Fig. 1). As with the Volvo XC60 described above, this AT features a wide ratio coverage (9.2) and centrifugal pendulum vibration absorber to reduce the engine speed, resulting in lower fuel consumption and noise. An electric oil pump was added to enable driving force on-demand. Use of this pump to control lubricant and coolant flows, and the incorporation of an idling stop mechanism also help to improve fuel

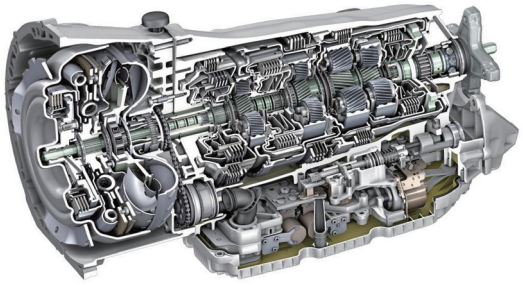

Fig. 1 Section view of Mercedes Benz 9-speed AT.

economy.

3. 4. Adoption of 9-speed AT in Range Rover Evoque

Range Rover has adopted a transverse 9-speed AT manufactured by ZF Friedrichshafen AG in the Evoque. This AT uses dog clutches at the two clutch elements to reduce drag loss, and a wide ratio coverage (9.8) to improve fuel economy. In addition to the dog clutch structure, the length of the transmission was reduced by providing two planetary gear sets in the radius direction, making it easier to install in front-wheel drive (FWD) vehicles (Fig. 2).

3. 5. Development of 12/16-speed AT for commercial vehicles by ZF

ZF is working toward the mass-production of a TraXon 12/16-speed AT for commercial vehicles (Fig. 3). Modular-based design enables the selection of dry clutch, dual clutch, torque converter, or hybrid (i.e., a clutch and motor configuration) take-off modules, an engine-dependent power take-off (PTO) module (called the NMV), or various types of PTOs that are independent of the engine. These configurations allow the user to customize the transmission for individual purposes.

3. 6. Adoption of automated manual transmission (AMT) for Suzuki Celerio

Suzuki has started production of a newly developed AMT called Auto Gear Shift, which is installed in the Celerio for the Indian market (Fig. 4). This AMT is a redesigned version of the base 5-speed MT featuring an additional electromechanical clutch actuator to enable automatic clutch and shift operations. On start, the driver can choose the automatic transmission setting or manual mode to increase usability while maintaining driving enjoyment.

4 CVT Trends

4. 1. Adoption of diesel engine CVT on Subaru Legacy Outback

The Legacy Outback for the European market is installed with a CVT designed for operation with a diesel engine. This CVT was made compatible with the high torque of a diesel engine by changing the torque converter characteristics and CVT fluid (CVTF) from the

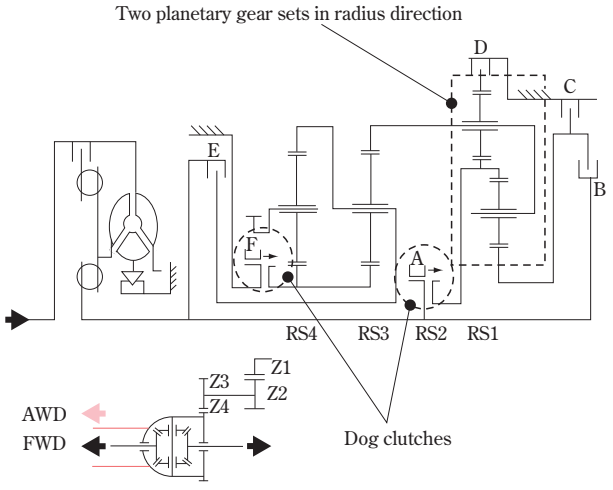

Fig. 2 Outline of ZF transverse 9-speed AT.

Fig. 4 AMT for Celerio.

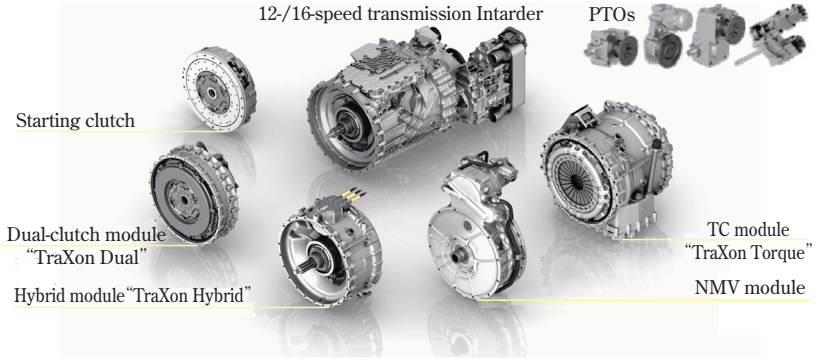

Fig. 3 Outline of ZF commercial vehicle 12/16-speed AT modules.

conventional model. The transmission achieves a shift feeling in tune with the tastes of the European market by operating as a conventional CVT at small accelerator opening angles and adopting AT-like shifting characteristics at larger opening angles.

4. 2. Refinement of CVT in Honda Fit

Honda has refined the CVT used in the Fit. The redesigned transmission is smaller, lighter and features a wider ratio coverage, allowing it to be installed in more models around the world. The driveability of the CVT can be adjusted to the tastes of each region by cooperative control between engine torque and the CVT ratio, which acts as the target value for driving force with respect to accelerator pedal operation.

4. 3. Trends of CVTs for mini-vehicles

The Nissan Dayz and Mitsubishi eK Wagon are installed with a CVT manufactured by Jatco Ltd., broadening the application of CVTs in mini-vehicles.

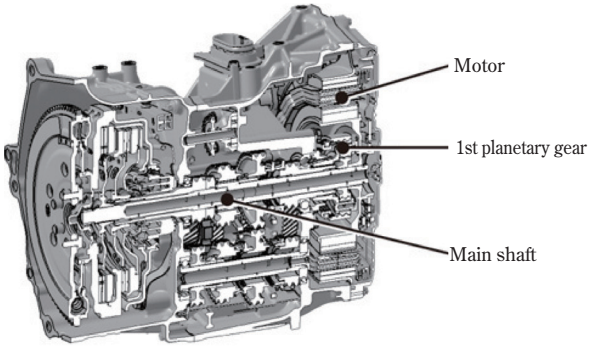

Fig. 5 7-speed DCT (i-DCD) for Fit Hybrid.

The Honda N-WGN has adopted an idling stop system that stops the engine at a vehicle speed of around 10 km/h without using an electric oil pump. Fast re-starts are achieved using an accumulator to supply the CVT hydraulic fluid.

The Suzuki Hustler has also adopted a CVT with an idling stop mechanism that does not require an electric oil pump. The same starting performance as the conventional mechanism was achieved by improving the sealing performance of the hydraulic pulley lines.

5 HEV Drivetrain Trends

5. 1. Adoption of 7-speed dual-clutch transmission (DCT) in Honda Fit Hybrid

The Honda Fit Hybrid uses a sporty 7-speed DCT system called the Intelligent Dual-Clutch Drive (i-DCD) (Fig. 5). This is a compact transmission that installs the planetary first gear inside the motor at the rear of the transmission. This DCT uses dry clutches.

5. 2. Adoption of transaxle in Honda Accord Hybrid

The Accord uses the newly developed Intelligent Multi-Mode Drive (i-MMD) hybrid transaxle (Fig. 6). In this configuration, the generator and the eigine, and the motor and the drive shaft are directly connected respectively, and a clutch is provided to engage and disengage the engine and drive shaft. With this transaxle, the vehicle drives away under motor power and switches to engine drive above a set speed, enabling driving modes that make optimum use of the torque and rotation speed

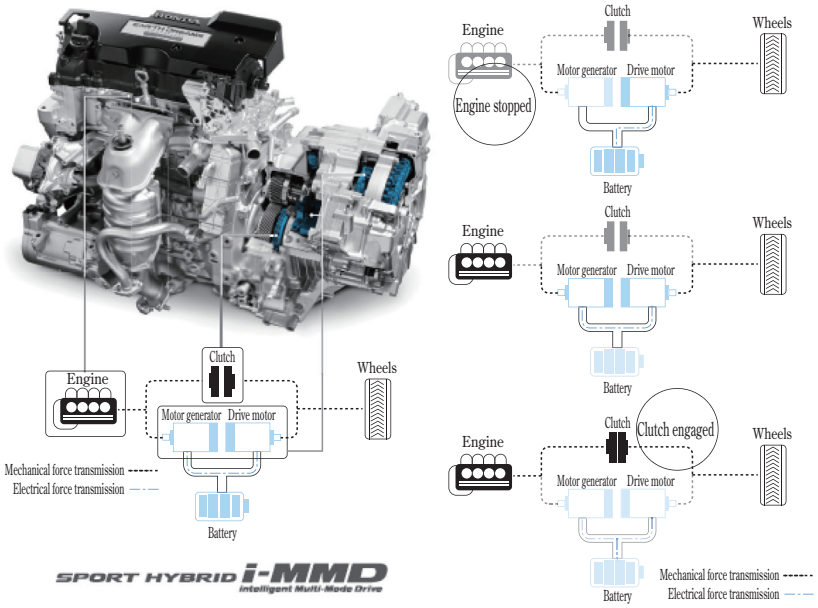

Fig. 6 i-MMD for Accord Hybrid.

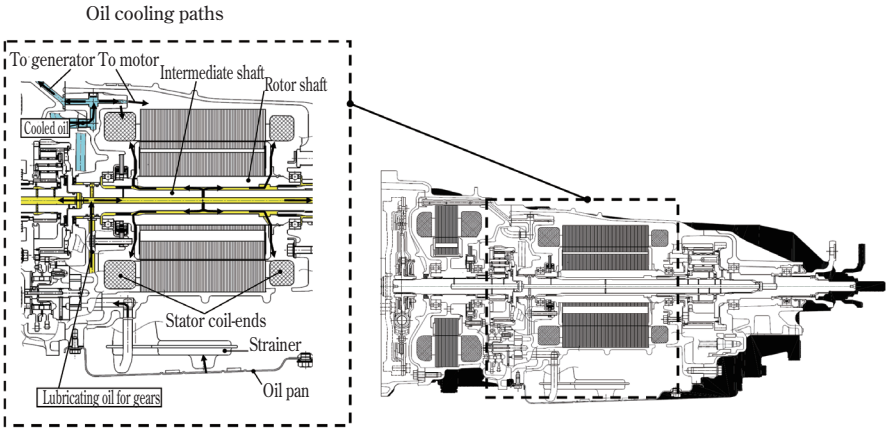

Fig. 7 RWD hybrid transmission.

characteristics of the motor and engine.

5. 3. Adoption of 2.5-liter rear-wheel drive (RWD) hybrid transmission by Toyota

Toyota has adopted a hybrid transmission manufactured by Aisin AW on the RWD Crown, Lexus IS, and Lexus GS models equipped with a 2.5-liter engine (Fig. 7). The conventional 2-speed reduction gear system used with 3.5-liter engines was replaced with a fixed gear ratio type to reduce the size and weight of the transmission for use with the smaller 2.5-liter engine. The cooling performance of this hybrid transmission was enhanced by a configuration that supplies coolant from an oil cooler directly to the motor to counter motor heating on high-torque gradients, and oil jets using the centrifugal force from the motor shaft center to the stator coil ends.

5. 4. Adoption of CVT in Nissan Pathfinder Hybrid

The Pathfinder Hybrid has adopted a FWD 1-motor 2-clutch CVT manufactured by Jatco (called the CVT8 hybrid) (Fig. 8). The clutches between the engine and motor are dry multi-plate type clutches. Optimizing the pushing position of the clutch pistons helped to reduce partial wear of the friction materials, and abrasion powder is expelled by the air flow created by clutch plate rotation.

5. 5. Adoption of CVT in Subaru XV Hybrid

Subaru has developed a full-time all-wheel drive (AWD) hybrid transmission for the XV Hybrid (Fig. 9). Based on Subaru's Lineartronic CVT, the drive motor is connected to the rear of the primary pulley, enabling the motor to drive the vehicle at low speeds (EV mode) and provide assist at medium and high speeds. To ensure the required CVT belt clamping force during EV mode, a motor drive path has been provided for the oil pump in addition to the path from the engine in the conventional CVT. The adoption of a one-way clutch enables independent drive by either the motor or engine.

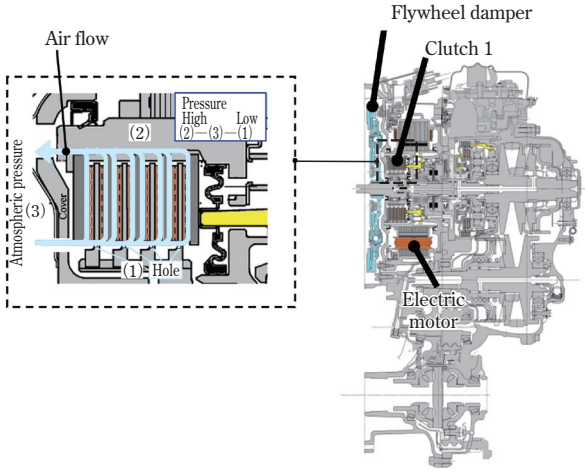

Fig. 8 CVT for Pathfinder Hybrid.

6 4WD Device Trends

6. 1. Refinement of 4WD system in Toyota Land Cruiser Prado

The 4WD system in the Land Cruise Prado features a refined Multi-Terrain Select function that allows the driver to switch between traction and brake controls to prevent the vehicle becoming stuck or losing speed on different surfaces. The four modes of the previous system have been increased to five, giving the vehicle greater off-road capability.

6. 2. Adoption of torque control 4WD system in Toyota Harrier

The Harrier features the Dynamic Torque Control 4WD system that switches automatically between FWD

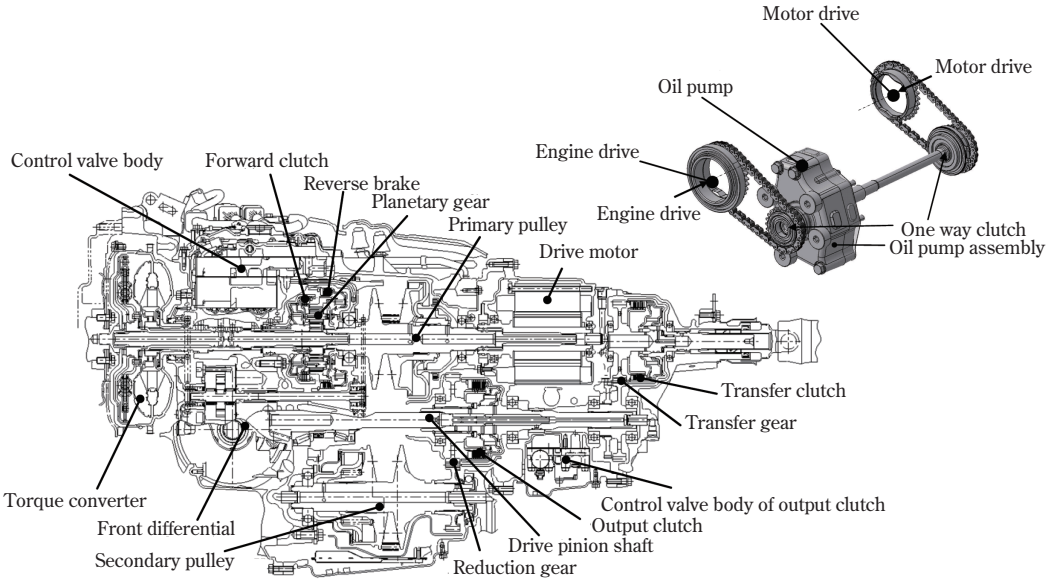

Fig. 9 CVT for Subaru XV Hybrid.

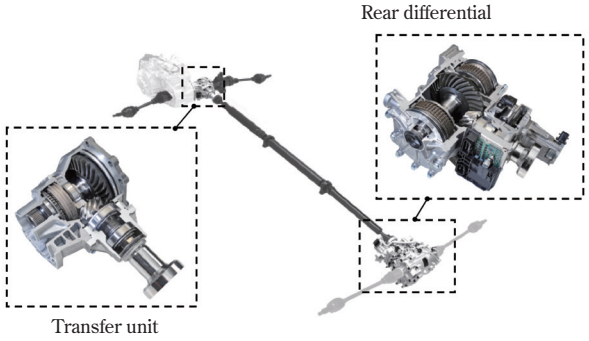

Fig. 10 GKN "disconnect" AWD system.

and 4WD settings. In normal driving, the vehicle switches to FWD to improve fuel economy. When starting and when driving on slippery surfaces, the vehicle ensures the appropriate driving force by distributing torque to the rear wheels. Furthermore, when turning, the system calculates the driver's required driving line from the steering angle and improves cornering performance on dry surfaces by distributing torque to the rear wheels in accordance with the vehicle behavior.

6.3. Adoption of "disconnect" system in Range Rover Evoque

The Range Rover Evoque includes the newly developed "disconnect" AWD system manufactured by GKN plc, which automatically switches between FWD and 4WD in accordance with the driving conditions and driver attention (Fig. 10). This system consists of a transfer unit capable of disconnecting the flow of torque to the rear wheels and a rear differential with two clutches that distribute torque to the left and right wheels. The rotating drivetrain components are disconnected in FWD mode to improve fuel economy.

7 Final Drive Gear Units

7.1. Refinement of hypoid gears in Nissan Q50

Nissan has adopted low-friction hypoid gears in the final drive gear unit of the Q50. Lower engagement friction was achieved by reducing the diameter of the hypoid gears and the pinion offset from the conventional unit. To counter the trade-off effects of reduced strength as well as lower noise and vibration performance, the rings gears were designed with smaller inner diameters, the necessary gear face width was secured, and the precision of the tooth profile was enhanced. As a result, the refined unit achieves the same performance as the conventional unit.

8 Drivetrain Research Trends

Research is continuing into ways of increasing CVT efficiency. For half-toroidal CVTs, a method of calculating efficiency considering elastic deformation was developed and identified a maximum feasible 1% improvement in efficiency. For belt-driven CVTs, research is examining stress generation prediction based on a detailed analysis of component parts and residual stress calculation based on nitriding simulations.

Model-based computer design is becoming more common and the application of analysis-led development

(ALD) is also spreading to transmissions. One research case reported a weight reduction of 15% by adopting computer-aided design (CAE) from the initial case structure development phase. Technology has also been developed to quickly and accurately calculate oil flows within a transmission considering gear engagements. There were also several examples of research into wet clutches. These included the development of technology to predict vibration behavior from the calculated torque transmission characteristics of the entire drivetrain, and high-response vehicle start technology using a physical model database of clutch engagement control. Other research examined dynamic contact pressure distribution measurement technology for a lock-up clutch using a thin-film sensor.

For part elements, a drive force transmission mechanism using magnetic resonance fluid (MRF) was developed and research was also reported into the friction reduction effect of a resin-coated tapered-land bearing.