DRIVETRAIN

1 Introduction

New vehicle sales in Japan (including mini-vehicles)[1] in 2018 exhibited a slight increase of 0.7% compared to the previous year. While sales of mini-vehicles increased from the previous year for a second consecutive year, the number of registered vehicles decreased from the previous year. The rise in consumption tax from 8% to 10% in October 2019, and the announced reduction of the automobile tax, are expected to provoke last minute demand or otherwise affect vehicle sales. With fuel efficiency and CO_2 regulations becoming stricter worldwide, the shift from internal combustion engine-driven vehicles to electric vehicles is predicted to accelerate due to the difficulty of complying with the regulations solely with internal combustion engines. In these circumstances, flexible approaches for electrification and improved efficiency in base elements are required for power transmission systems. This article summarizes the latest power transmission systems released in the automotive industry in 2018, and also introduces proposed technologies paving the way for next-generation power transmission systems.

2 Manual Transmission (MT) Trends

2.1. Toyota Corolla Sport 6-speed FF Manual Transmission (BK6)[2]

Aisin AW mounted the newly developed BK6 intermediate-capacity 6-speed FF manual transmission on the Corolla Sport released in August 2018. To enhance competitiveness compared to the previous BH6 model, the BK6 is downsized by 24 mm in overall length and is 7 kg lighter. This was achieved by reducing case thickness and employing a 2.5-shaft structure. The 2.5-shaft structure eliminates the conventional reverse idler gear, integrating it into the 1st gear, and sets a short shaft as output No. 2, thereby allowing a shorter input shaft (Fig. 1). A 23% reduction in the case mass was achieved by securing rigidity at the necessary locations via CAE analysis of castability, stress, and NVH and reducing thickness at other locations to optimize the overall mass. The Intelligent Manual Transmission (iMT) that assists gear shifting and starting operation is adopted in the BK6, allowing drivers to enjoy manual operation. The iMT computer controls the engine speed to an optimum engine speed that matches the driver's clutch and shifting operations, providing constant support for smooth starting operations.

3 Automatic Transmission (AT) Trends

3.1. Honda US Accord 10-speed FWD Automatic Transmission[3]

The Accord Odyssey destined for North America released in 2017 is equipped with the world's first 10-speed FWD AT. In an effort to match the development concept of compact size and a high level balance between an exhilarating driving experience and fuel efficiency, the ten speed have a 10.1 ratio, and the total number of elements, namely the sum of the number of clutches and the number of planetary gear sets (PGSs) was set to seven or less in consideration of the overall length. As a result, the AT contains four PGSs, three clutches, and four brakes. To reduce size, gears with both internal and ex-

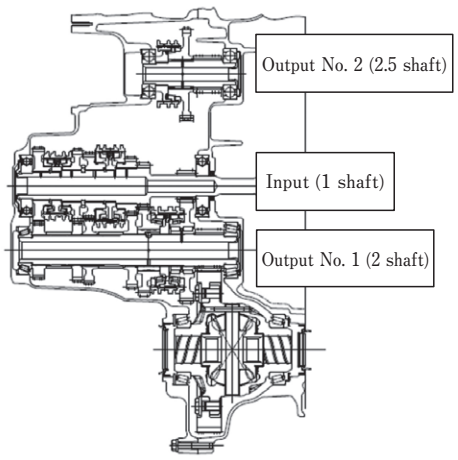

Fig. 1 S tructure of Aisin BK6 AW 6-speed FF MT

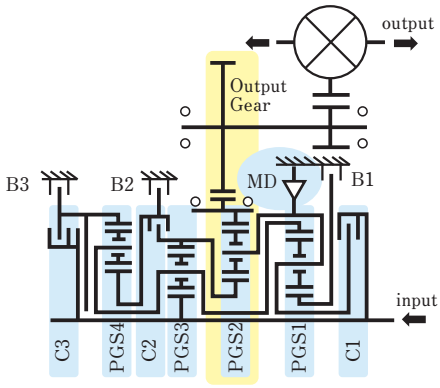

Fig. 2 Schematic Diagram of Honda 10-speed FWD AT

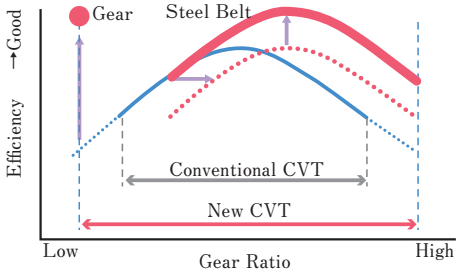

Fig. 3 Concept of Toyota Direct Shift-CVT

ternal teeth were adopted and the output gear and the PGS2 were arranged to overlap each other. The low/reverse brake was replaced by a mechanical forward and reverse switching device (MD) consisting of a ratchet-type forward-rearward switching mechanism to reduce drag resistance as well as size. Consequently, the 10-speed AT achieves an overall length and vehicle mountability equivalent to those of a 6-speed AT (Fig. 2).

4 Continuously Variable Transmission (CVT) Trends

4. 1. Lexus UX CVT (Direct Shift-CVT)[4]

The Lexus UX released in November 2018 is equipped with a newly developed metal belt 2.0 L Direct Shift-CVT. In an effort to improve fuel efficiency and dynamic performance, Toyota adopted a power transmission mechanism with launch gears, a world-first technology in metal belt CVTs, and restricted the belt to the high efficiency range by placing it near the high gear ratios, thereby achieving improved transmission efficiency and a wider gear range (Fig. 3).

The engagement and disengagement of C1 and C2 enables switching between the gear-drive and belt-drive transmission paths, which secures both starting acceleration and fuel efficiency. Newly added launch gears de-

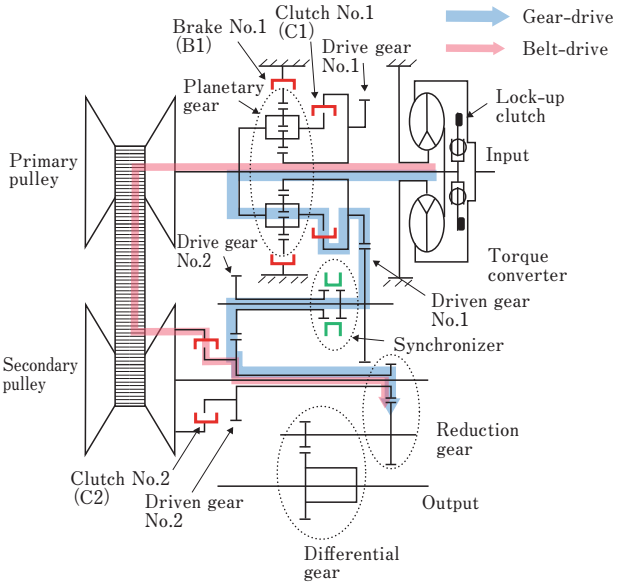

Fig. 4 Schematic Diagram of Toyota Direct Shift-CVT

Fig. 5 External View of Honda N-Van CVT Unit

crease in fuel efficiency in high-speed ranges, an issue resolved by adopting a synchromesh mechanism for the launch gears to detach the loss-causing elements (Fig. 4).

4. 2. Honda N-Van CVT

The N-Van released in July 2018 is equipped with a newly developed metal belt CVT. Based on the CVT revamped in the second generation N-Box released the previous year, the unit provides the smooth running feel unique to CVTs and high fuel efficiency while maintaining high reliability, enabling the N-Van to withstand use as a commercial vehicle (Fig. 5).

Stronger parts are required to make the N-Van suitable for commercial use. The number of rings in the metal belt was increased from 9 to 12 to disperse stress applied to the rings, improving belt durability. A high-strength material was used for the final drive gear, and the face width of the driven gear was increased by 2

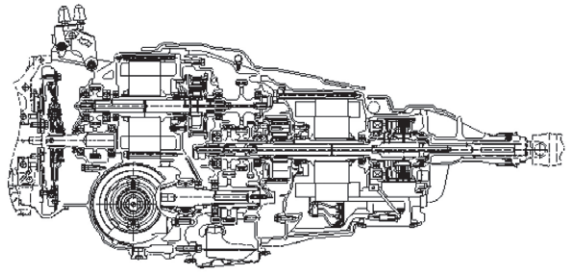

Fig. 6 Structure of Subaru Plug-in Hybrid Unit

mm. The ratio coverage was set to achieve usability as a commercial van and smooth gear shifting control is provided to avoid load collapse. The fuel-efficient technologies (e.g., a 2-system discharging oil pump system and reduced pulley hydraulic) used in the N-Box were incorporated in the N-Van CVT, significantly improving fuel efficiency for a commercial vehicle.

5 Drive System for Hybrid Vehicles

5. 1. Subaru New Plug-in Hybrid Unit[5]

A new unit for plug-in hybrid vehicles developed by Subaru was mounted on SUVs destined for North America released in 2018. The plug-in hybrid unit inherits the traditional Subaru symmetrical AWD, achieving both top-class fuel efficiency and excellent dynamic performance (Fig. 6).

The unit is equipped with a motor that charges the high-voltage batteries and supplies drive power (MG1) and a motor that serves as an auxiliary power source for the engine and assists engine output according to driving conditions (MG2). The unit also has a power splitting mechanism that splits power from the engine to MG1 and the output shaft, a motor reduction mechanism that transmits power from MG2 to the output shaft, a speed reduction mechanism, and a differential mechanism. The reduction gear ratio was determined based on simulations of fuel efficiency and dynamic performance that take gear noise into account to achieve the target for higher environmental performance.

6 4WD Device Trends

6. 1. Honda CR-V Real Time AWD System[6]

A 4WD specification was added for the first time to the Sport Hybrid i-MMD mounted on the CR-V released in November 2018. The 4WD system is the Real Time AWD System in production since 2011, which reduces weight and friction for better fuel efficiency, and decreases the slip amount for improved startability. The Real Time AWD System actively controls a motor-driven pump. The overall configuration of the system consists of a dedicated 4WD ECU that calculates various pieces of vehicle information transmitted from the engine, transmission, and Vehicle Stability Assist (VSA) ECUs, and controls the clutch in the rear drive unit. To reduce weight, parts were downsized or eliminated through electronic control and by adopting hydraulic circuits without leakage. To reduce friction, the main parts causing sliding resistance were eliminated through electronic control. Hill-climbing control increases the distribution of the drive force to the rear wheels at or above a predetermined gradient, allowing starting operation with less slipping compared to the previous system. Consequently, weight was reduced by 17% and friction by 60% compared to the previous system, improving stable startability.

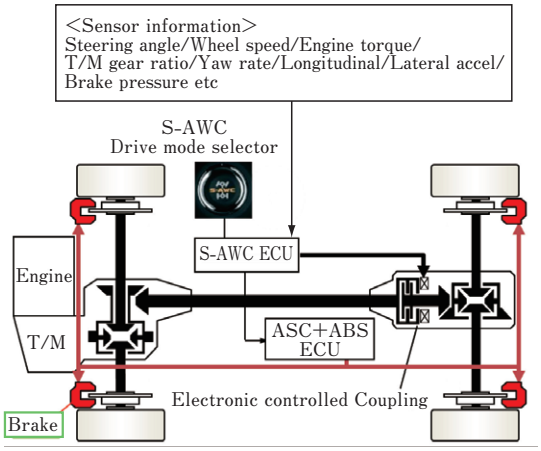

Fig. 7 Mitsubishi Eclipse Cross S-AWC System

6. 2. Mitsubishi Eclipse Cross S-AWC

The Eclipse Cross released in March 2018 is equipped with a new 4WD system S-AWC. The S-AWC integrally controls the 4WD electronic control that distributes drive force to the rear wheels and the Active Yaw Control (AYC) that controls drive force and braking force between the right and left wheels via the brakes (Fig. 7).

The S-AWC ECU is connected to sensors and other ECUs via CAN communication lines to detect driver operations and vehicle behavior. Based on that information, the S-AWC ECU controls the electronic control coupling in the rear differential assembly and the brakes to optimize vehicle behavior.

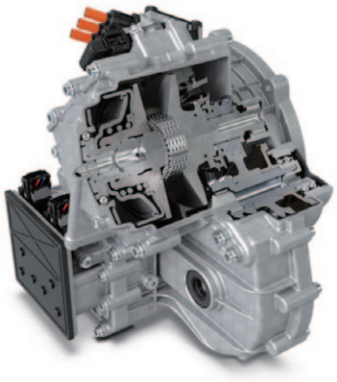

Fig. 8 External View of Schaeffler DH-CVT

7 Drivetrain Research Trends

The hybrid capabilities of PHEVs enable a fun-to-drive experience with fuel-efficient, low emissions performance. As regulation requirements become stricter, battery capacities will expand, and output from electric energy due to improved performance will continue to increase. Demand for electric powertrains is expected to keep growing, which means that optimizing the overall system is becoming a priority issue. Schaeffler has been developing and manufacturing power transmission chains, a main component of CVTs, and has accumulated knowledge on CVT system design. This article takes a look at the DH-CVT[7] using the P2 layout, which was based on CVTs (Fig. 8).

The electric motor has a max power of 90 kW and a max torque of 330 Nm, and a compact overall length of 3403 mm. As a result of investigating the influence of the ratio spread on fuel efficiency, a ratio spread of 7 was chosen. The variator can be separated from the wheel side using a dog clutch behind the secondary pulley set. This means that the battery can still be charged with the motor, even when the vehicle is stationary. Building on existing approaches to actuator technology, Schaeffler has proposed separating the clamping and shifting functions and installing two electric pump actuators that can be controlled as required. Such a pump structure reduces the average power required from the pumps during the WLTC test. This represents a fuel economy benefit of approximately 4% compared to a standard hydraulic system.

The future development of drive systems will require flexibly adaptation to electrification and further high efficiency of conventional technologies. Industry-academia collaboration carried out via the Transmission Research Association for Mobility Innovation (TRAMI) established in 2018 is expected to lead to more widespread development of basic technologies.

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