DRIVETRAIN

1 Introduction

In contrast to sales of new vehicles in Japan in 2015 (including mini-vehicles)[1], where the repercussions of the 2014 consumption tax increase and the raising of the tax on mini-vehicles resulted in −9.3% drop, global sales rose by 2.0% compared to the previous year, particularly in North America and China. In addition to the ongoing development of technologies aimed at improving fuel efficiency in response to the increasing global spread of environmental awareness, technological breakthroughs are being pursued in initiatives to improve safety performance as well as research and development focusing on automated driving. This article summarizes the latest power transmission systems released by the automotive industry in 2015, and also takes a look at the technological trends paving the way for next-generation power transmission systems.

2 Clutch Trends[3]

2. 1. Schaeffler MTplus automatic clutch system

In Europe, where demand for manual transmission (MT) vehicles is high, technological development for MT vehicles with three pedals is actively conducted, automatic clutches adapted to sailing (a fuel-saving driving strategy) are being developed. Schaeffler developed the MTplus, which simply adds a relatively simple actuator to a conventional clutch (Fig. 1). The demand for automatic clutches is likely to grow not just in terms of sailing, but in step with advances in MT-related pre-collision and automated driving technologies.

3 Manual Transmission (MT) Trends

3. 1. Mazda Roadster 6-speed MT[4]

A new 6-speed manual transmission was developed for the latest Roadster model (Fig. 2). Technologies such as (a) a direct drive configuration for the 6th gear, (b) lower input reduction gear ratios, (c) main axis layout for all synchronizer ring stages and, (d) low viscosity gear oil were incorporated to realize the Roadster's agile and fun driving. Advances in the development process for the cases led to the use of a case with no ribs and uneven thickness that fulfills strength, rigidity, and NVH performance with the minimum necessary mass.

3. 2. BMW Active Tourer 6-speed T[5]

The BMW 2 Series Active Tourer uses a transverse 6-speed transmission (BG6) build by Aisin AI (Fig. 3). Enhanced noise and vibration performance has been achieved through revising the shift structure for better diagonal shift performance, modifications to the gear machining process, and the optimization of the case.

3. 3. Honda S660 6-speed MT[6]

A new 6-speed manual transmission has been developed for the new S660 two-seater open-top sports car. It supports a maximum input torque of 104 Nm, and the first five gears were configured with close ratios to take advantage of the engine characteristics, while the sixth gear was set to a cruise ratio for enhanced quietness during high-speed cruising. The nimble handling of a sports car was made possible by setting a short stroke, and load displacement characteristics during gear shifting were optimized to achieve a smooth and crisp shift feeling. At the same time, characteristic three-cylinder engine noise caused by rotational speed fluctuation was reduced by adopting a no-backlash gear and friction washer.

4 Automatic Transmission (AT) Trends

4. 1. Mazda Demio 6-speed AT[4]

A compact 6-speed automatic transmission (SKYACTIV-Drive) was developed in two variations adapted, to respectively, the torque capacity of the 1.3-liter gasoline engine and the 1.5-liter diesel engine mounted in the new Demio (Fig. 4). The compact SKYACTIV-Drive for the gasoline engine supports a torque capacity of 165 Nm, and almost all of its parts are dedicated designs. Building

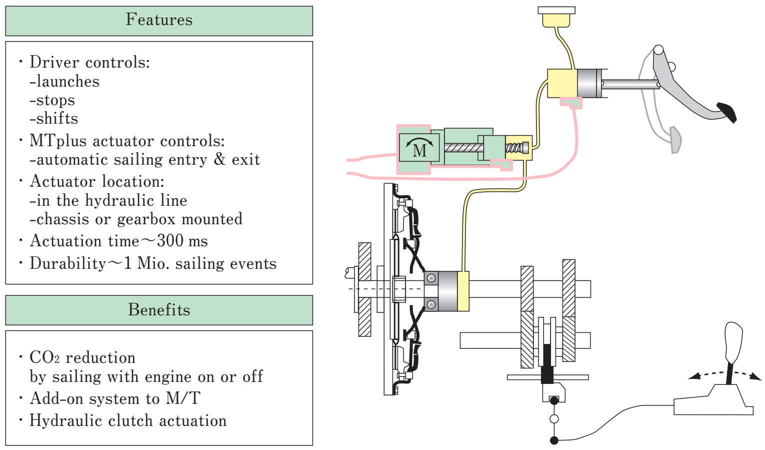

Fig. 1 Schaeffler MTplus automatic clutch system.

Fig. 2 Mazda Roadster 6-speed MT.

Fig. 3 BMW Active Tourer 6-speed.

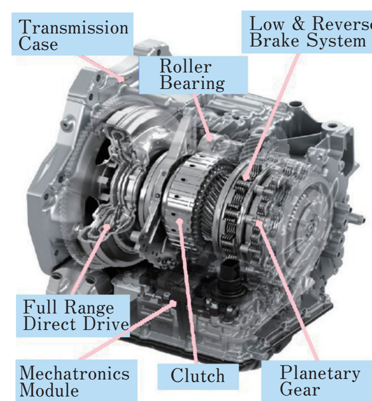

Fig. 4 Compact SKYACTIV-Drive for the new Mazda Demio.

on the basic concept of the previously commercialized medium-sized SKYACTIV-Drive, it eliminates the one-way clutch and adopts a torque converter with a low rigidity lock-up damper to decrease size and weight and reduce noise and vibration. In addition, smooth starts and a direct feeling are both achieved through improved lock-up response provided by a centrifugal cancellation mechanism and the optimization of the gear ratio.

The SKYACTIV-Drive used for the diesel engine is a compact design based on the medium-sized SKYACTIV-Drive used with the 2.0- and 2.5-liter gasoline engines in the CX-5, Atenza, and Axela. The shaft support structure was extensively revised to reduce center distance for inputs and outputs, making it possible to fit a compact SKYACTIV-Drive for diesel engines that supports a torque of 270 Nm within the limited space available in a compact car. Lock-up starting in the low engine speed range has been achieved by switching to high damping dampers and controlling vibration.

4. 2. GM automatic transmission[7]

Automatic transmissions that replace the conventional electric oil pump with an accumulator for stop/start functionality have been announced as 6- and 8-speed ATs for 2016 models. This reflects the expansion of stop/start systems for improved fuel economy and cost reduction concerns centered on the U.S. market.

5 CVT Trends

5. 1. Nissan Lannia CVT[8]

Jatco Ltd. and Nissan have jointly developed the Jatco CVT7 W/R (which stands for wide range), a CVT for compact front-wheel drive vehicles that exemplifies newly developed environmental technology aimed at improving fuel economy in internal combustion engine-driven

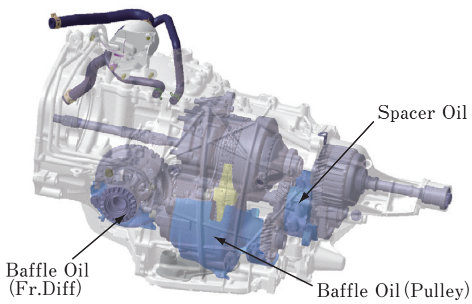

Fig. 5 Lineartronic CVT for the Subaru Levorg.

vehicles.

Based on the Jatco CVT7, this new Jatco CVT7 W/R enhances driving performance through the use of technologies such as active slip control to prevent excessive engine pick-up response when starting off and D-step control to provide a sporty driving experience. Newly developed belts and improved pulleys expanded ratio coverage to 8.7, the largest in the world for a CVT, and the adoption of an enhanced, compact oil pump achieves improved fuel efficiency (3%) by reducing friction. The new transmission is produced at the Jatco (Guangzhou) Automatic Transmission Ltd. production plant in China, and installed in the new Lannia model launched in the Chinese market.

5. 2. Subaru Forester Lineartronic[9]

The new Forester model is equipped with a new Lineartronic CVT featuring improved environmental as well as noise and vibration performance. The stirring resistance of the oil was reduced by introducing spacer oil and a front baffle, enlarging the pulley baffle, and adding discharge openings for the clutch lubricant.

The new lock-up damper first introduced in the Levorg was used to reduce damper rigidity characteristics. This expanded the lock-up range, simultaneously reducing fuel consumption and booming noise. Furthermore, oil pump noise has been reduced by improving case rigidity, switching to roller bearings for the pulley, reducing chain noise through a modified soundproof cover shape and a new oil pump rotor tooth profile. These improvements mitigate noise and vibration from the transmission when the vehicle is in motion, providing a better driving feel (2.0-liter NA models).

6 HV Drivetrain Trends

6. 1. Toyota Prius transaxle[9]

Toyota Motor Corporation and Aisin AW Co., Ltd. jointly developed the FF2 motor hybrid transmission for

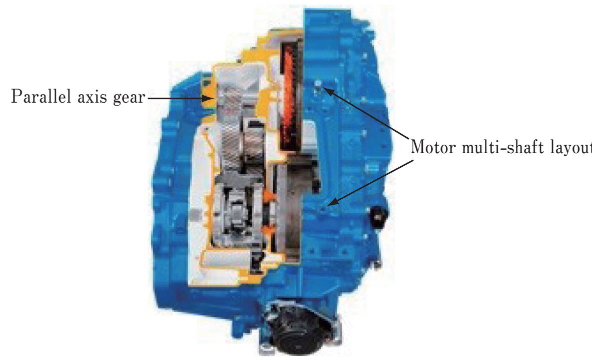

Fig. 6 Toyota Prius transaxle

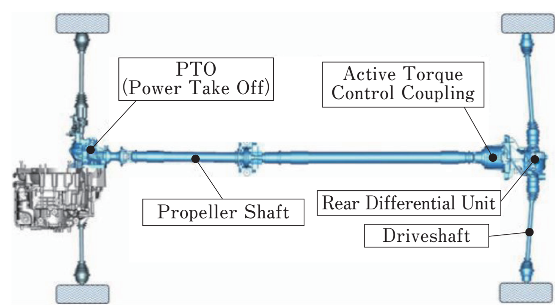

Fig. 7 Mazda CX-3 AWD

the new Prius (Fig. 6).

The layout of this new two-motor hybrid transmission was completely revised to make it more compact and more fuel efficient. This led to an overall length 47 mm shorter than the previous model, and also achieved a 20% reduction in losses. The transmission now uses a multi-shaft layout where the motors are mounted on separate shafts. At the same time, the reduction gears that amplifies torque from the motors have been changed from a planetary gear to a parallel axis gear arrangement.

6. 2. BMW 225xe plug-in hybrid[11]

The BMW 225xe Active Tourer combines an inline 3-cylinder BMW TwinPower Turbo engine that has a maximum output of 100 kW (136 ps) with electric motors that have a maximum output of 65 kW (88 ps) to provide a plug-in hybrid system that boasts a maximum total system output of 165 kW (224 ps). The engine drives the front wheels via a 6-speed transmission while the electric motors drive the rear wheels, making it a four-wheel drive system.

7 4WD Device Trends

7. 1. Mazda CX-3 AWD[4]

An AWD system for the new Demio CX-3 was devel-

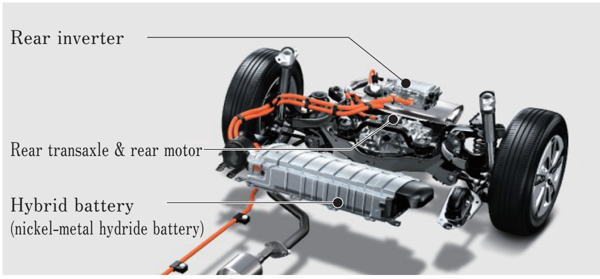

Fig. 8 Toyota Prius HV 4WD (E-Four)

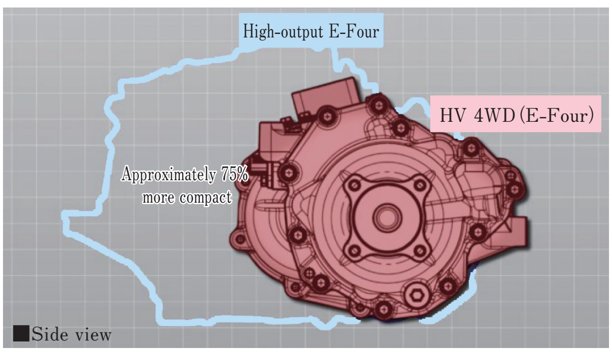

Fig. 9 Toyota Prius HV 4WD (E-Four)

oped using the AWD system used in the CX-5 and later products as a base(Fig. 7). The system balances rough road performance, handling stability and controllability, and fuel economy.

7. 2. Toyota Prius HV 4WD (E-Four)[12]

The HV 4WD system (E-Four) available on the Toyota Prius automatically controls the transition from front- to four-wheel drive in accordance with driving conditions during normal operation. The system helps with start performance and driving stability by smoothly switching to four-wheel drive in slippery conditions such as when accelerating or driving on snowy roads. Excellent handling stability and controllability is offered by optimizing the front and rear torque distribution according to the state of the vehicle during cornering (Figs. 8 and 9).

In day-to-day driving, the system provides assistance with starts by distributing drive force to the rear wheels rather than using only the front wheels. It then controls the distribution ratio between the front and rear wheels between 10:0 and 4:6 according to driving conditions for speeds up to 70 km/h.

A magnet-less induction motor was adopted as a means of lowering fuel consumption fuel, cutting down on energy losses from the drag resistance caused by magnetic force. In addition, internal oil resistance was also given consideration, and oil surface height was lowered by setting an oil catch tank, reducing stirring resistance. In terms of both mass and size, the HV 4WD (E-Four) system unit is 75% more compact than the high-output E-Four system, providing almost the same amount of luggage space as in 2WD vehicles. Where past systems used a configuration with three independent drive shafts for the motor, reduction gear, and differential shafts, this system achieves a 75% more compact side view by integrating the motor and reduction gear shafts to produce a two-shaft configuration.

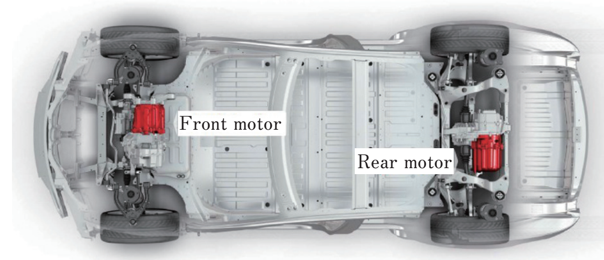

Fig. 10 Tesla Model S dual motor AWD

7. 3. Ford Focus RS Performance AWD[13]

The Focus RS features the Ford Performance All-Wheel Drive system. The twin electronically-controlled clutch packs set on each side of the rear drive unit (RDU) control both the front/rear and side-to-side torque distribution, to achieve torque vectoring that has a dramatic impact on handling and cornering stability. A maximum of 70% of the drive torque can be diverted to the rear axle, and up to 100% of that rear axle torque can be sent to each rear wheel. At the same time, a new gear ratio makes it possible to drive the rear wheels earlier than the front wheels in AWD mode, and cornering performance is increased by distributing significant drive force to the outside rear wheel when making turns.

7. 4. Tesla Model S dual motor AWD[14]

The Model S is equipped with a dual motor all-wheel drive system (Fig. 10). Two motors, one each on the front and rear axles, provide independent digital control of the front- and rear-wheel torque.

Each of the motors in the Dual Motor Model S is smaller than the motor in the rear-wheel drive Model S, and their light and efficient build improves cruising distance and acceleration. The combination of the high performance rear motor and high efficiency front motor achieves acceleration to 100 km/h in 3.0 seconds.

8 Drivetrain Research Trends

In the past, environmental performance initiatives by automakers in the context of drivetrains have involved the development of technologies focused on reducing friction in all locations. Now, manufacturers are announcing loss reduction technologies involving achieving efficient running through coordination between the engine and power sources like electric motors, and shutting off (disconnecting) the power in situations where it is not required, such as coasting. Furthermore, in the rapidly advancing field of automated driving, an evolution starting with automatic braking, and continuing with following of the vehicle ahead, lane keeping, and fully automatic parking is pushing drivetrain and shifting technology research and development targeting fully automated forward. Vehicle and drivetrain development will be expected to complement the perpetual initiatives to improve fuel economy with efforts that achieve both driving pleasure and driving automation.

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