DRIVETRAIN

1 Introduction

New vehicle sales in Japan (including mini-vehicles)[1] in 2016 dropped by 1.5% compared to the previous year. In particular, there was a significant decrease in sales of mini-vehicles. New vehicle sales in the global market have grown strongly, increasing by 4% compared to the previous year to set a record. By region, sales in the US, China, Eastern Asia and Oceania reached a record-highs, bringing sales figures up.

Both developed countries and emerging countries have been strengthening their environmental regulations, making it necessary to meet environmental requirements for zero-emission vehicles (such as electric and fuel cell vehicles) and plug-in hybrid vehicles. Divetrains must also be adapted to major changes. At the same time, the performance of conventional units has steadily improved. This article summarizes the latest power transmission systems released in the automotive industry in 2016, and also takes a look at the technological trends paving the way for next-generation power transmission systems.

2 Manual Transmission (MT) Trends

Magna T215 Manual Transmission[2]

Magna has developed a new 5-/6-speed FWD manual transmission. It achieves high unit efficiency with a torque capacity of up to 215 Nm and the adoption of low-loss oil (Figure 1). It also weighs approximately 20% less than the previous unit. Enhanced shifting performance is achieved with the adoption of multi-synchronizer rings for low gear positions and synchronizer rings for reverse gears.

3 Automatic Transmission (AT) Trends

Lexus LC500 10-speed RWD Automatic Transmission

The new 10-speed RWD automatic transmission mounted in the new Lexus LC500 was developed to offer both driving appeal and high fuel efficiency worthy of a next-generation premium vehicle (Figure 2). This transmission focuses extensively on driving appeal to achieve rhythmical, smooth and highly responsive gear changes, realizing drivability at a higher level than ever before.

The newly developed gear train produces a 10-speed AT that uses the same number of elements as the existing 8-speed AT. The gear ratio is meticulously set to provide drivers with a uniform shift change interval and features ideal cross gear steps that provide a seamless acceleration feeling. To achieve direct driving feeling and lower fuel consumption, this transmission was designed to apply lock-up starting at low speeds, and reduced the inertia of the torque converter.

The newly developed torque converter uses a high performance damper with a dynamic damping structure using a torus-shaped turbine as mass. Also, the small

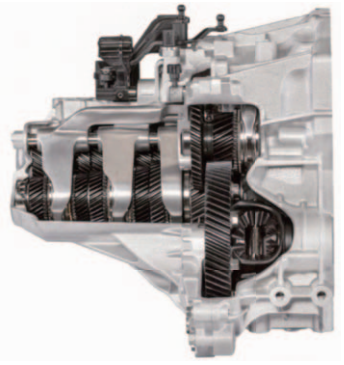

Fig. 1 Magna T215 Manual Transmission

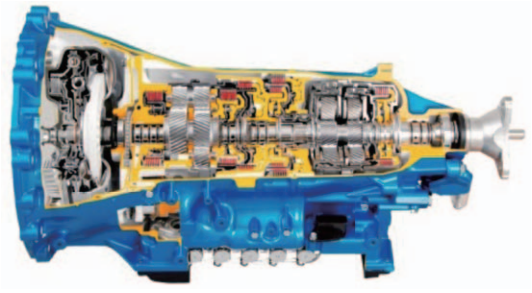

Fig. 2 10-speed RWD Automatic Transmission

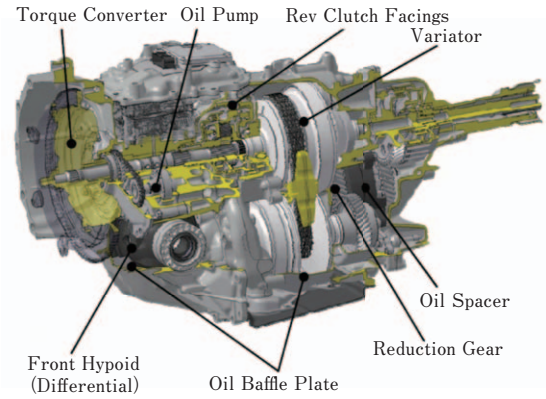

Fig. 3 Lineartronic

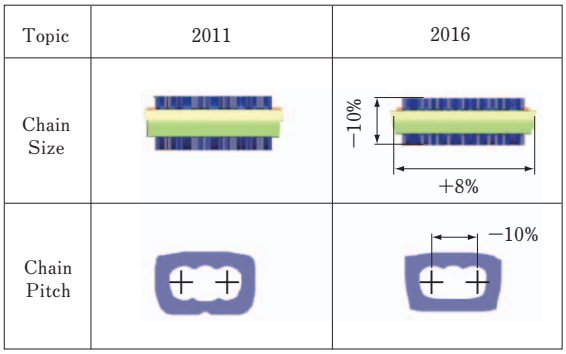

Fig. 4 Chainbelt Specifications

multiplate clutch improves lock-up control and slip heat resistance, allowing lock-up starting at lower speeds.

With optimally allocated linear solenoids and valves, the newly developed hydraulic control system reduces resistance in the oil pipe path by up to 67%, which contributes to achieving highly responsive gear change. Even as development gave gear change characteristics top priority, weight was reduced by 4.9 kg compared to the existing 8-speed AT, and fuel efficiency was improved by 6.7%.

4 Continuously Variable Transmission (CVT) Trends

SUBARU Impreza Lineartronic(3)

The Lineartronic intermediate-capacity longitudinally-mounted chain-type continuously variable transmission has been improved significantly in terms of environmental performance and dynamic quality (Figure 3) in an effort to match the development concept of the new platform adopted with the new Impreza released in October 2016. Carrying over appearance dimensions and basic structures from previous specifications, some components were improved to enhance performance. In particular, the world's first variators with short pitch chains (Figure 4) were produced to improve noise and vibration performance. The overdrive gear ratio was also raised by securing a ratio coverage of 7.0, the highest in a CVT without an auxiliary transmission. This reduces engine speed while ensuring standing start acceleration performance.

In total, energy loss for the entire transmission has been reduced by16% (at constant speed of 80 km/h) through the lower drag torque resulting from the adoption of low-friction facing in the reverse clutch, the drop in oil mixing resistance achieved by changing the shape of the baffle plate of the front hypoid gear and pulley, and the lower oil level height obtained by setting an oil spacer to suppress oil movement during acceleration and deceleration.

Furthermore, the exclusive design that restricts the applicable displacement of the torque converter to a maximum 2.0 liters enabled a 35% reduction in weight by decreasing the torus diameter from ϕ 236 to ϕ 215, and the use of fixed welding for front hypoid gear (eliminating bolts), along with a thinner transmission case (minimum thickness of 2.5 mm), further reduced weight by 5%.

5 Drive System for Hybrid Vehicles

5. 1. Nissan Note e-Power

The Nissan Note e-Power is a new form of electric vehicle that allows users to drive as far as they like without having to worry about charging. The e-Power is driven solely by a motor that uses electricity generated by the engine instead of external charging. It therefore provides a powerful and smooth driving feel, excellent fuel efficiency, and the distinctive quietness of a motor drive.

Figure 5 shows the dedicated e-Power gear box, and Figure 6 shows the appearance of the powertrain used in the e-Power. The power generating engine is placed on the right side of the vehicle while the driving and power generating motors are placed on the left, and the thin gear box is set between the two. The gear box consists of a reducer (3-axis 2-step, gear ratio: 7.388) that transmits power from the driving motor to the driveshaft, and a multiplier (3-axis 2-step, gear ratio: 0.6) that transmits power from the engine to the power generat-

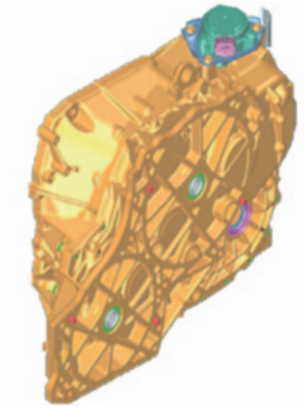

Fig. 5 e-Power Gear Box

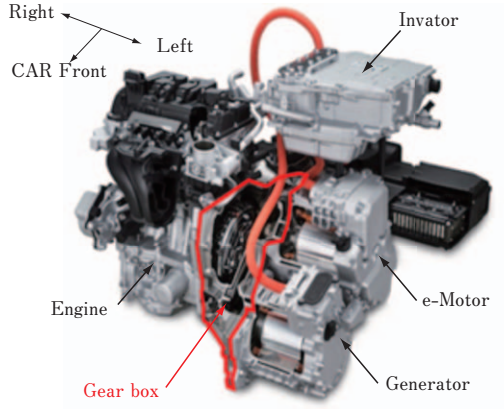

Fig. 6 Appearance of e-Power

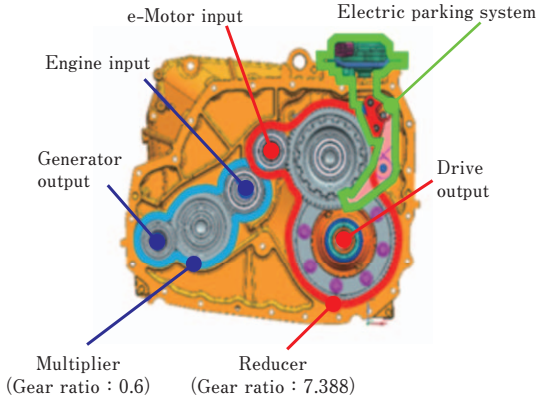

Fig. 7 Internal Structure of the Gear Box

ing motor (Figure 7). The optimized oil flow circulation structure reduces the oil volume to 1.93 liters, which also reduces friction to establish a low-cost, reliable oil circulation system.

5. 2. Lexus LC500h Multistage Hybrid Transmission

Toyota Motor Corporation has developed the world's first multistage hybrid transmission (L310) that achieves high levels of fuel efficiency and driving performance.

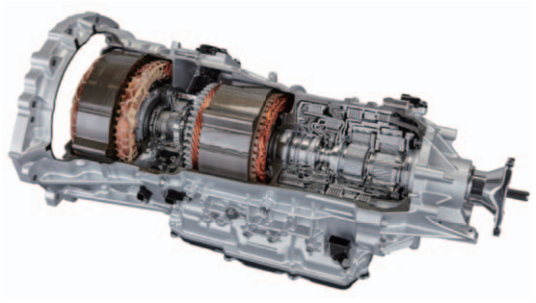

Fig. 8 Lexus LC500h Multistage Hybrid Transmission

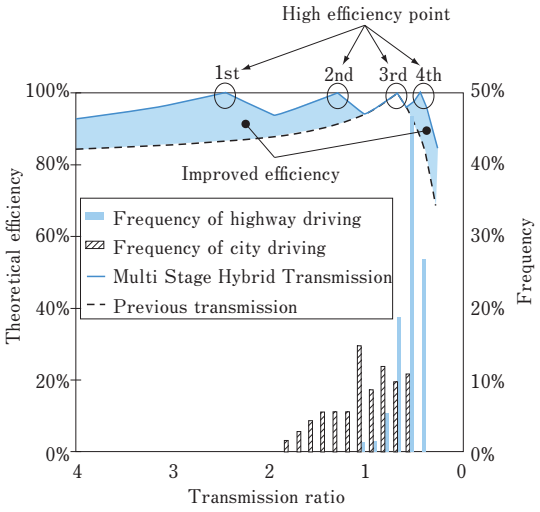

Fig. 9 Theoretical Transmission Efficiency

The characteristics of L310 are presented below.

The main purpose of developing the L310 was to significantly improve fuel efficiency during highway driving. Specifically, high efficiency points have been added in the speed increasing ranges of the transmission (Figure 9). This was achieved by setting a suitable 4-speed gear ratio in the gear shifting mechanism arranged in line with the power split device.

Another development goal was to realize the highest power performance among hybrid vehicles of the same class. This was achieved by setting a suitable first speed gear ratio in the gear shifting mechanism arranged in line with the power split device to amplify the engine and motor torques.

6 4WD Device

Honda NSX

Announced in 2016 and released in February 2017 in the wake of its first complete redesign in 26 years, the NSX adopts the Sport Hybrid SH-AWD® (Super Handling-All Wheel Drive) system, which represents the lat-

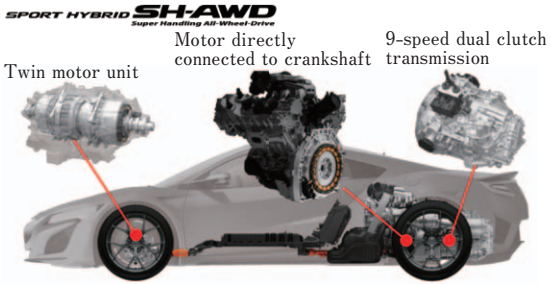

Fig. 10 Sport Hybrid SH-AWD®

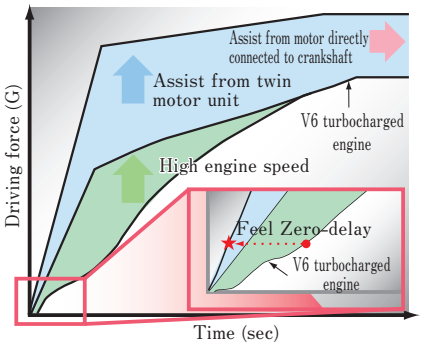

Fig. 11 Visualization of Driving Force Performance

est original technology that achieve ideal driving performance and uses the driving force of the motor during acceleration and cornering. The NSX redefines the joy of driving through a high level of responsiveness and handling performance unlikely to be achieved only by engines.

The Sport Hybrid SH-AWD® is a newly-developed high efficiency, high power three-motor hybrid system. It combines a highly efficient motor directly connected to the crankshaft of the mid-engine layout, V-configuration 6-cylinder twin turbocharged engine, a 9-speed DCT (dual clutch transmission), and independent motors on the front right and left sides of the vehicle that enable torque vectoring (Figure 10). This provides linear and powerful acceleration (Figure 11) as well as better cornering performance (Figure 12).

Thanks to the Integrated Dynamics System selects the optimal vehicle characteristic from one of four modes according to the situation, the NSX is equally suited to

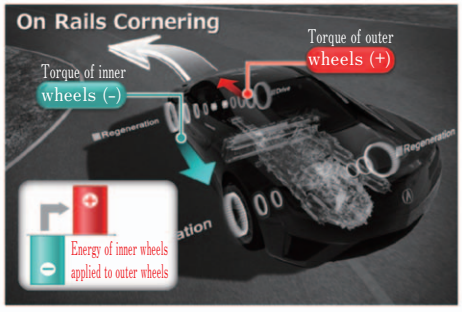

Fig. 12 Visualization of Torque Vectoring

everyday driving and circuit sports driving, making it a super sports car that provides enjoyable driving in a wide variety of situations.

7 Drivetrain Research Trends

Further improvements and adaptations of electric and plug-in hybrid electric vehicles are increasingly required to address environmental issues. Even the racing industry, traditionally perceived as unconcerned with the environment, is now holding races for electric formula cars (FIA Formula E Championship), underscoring the need to address electrification in the development of drive systems. Nevertheless, the need for conventional internal combustion engines remains high in emerging countries. Enhance the environmental performance of those engines will continue to require drive system-based initiatives such as reducing friction in various locations, further expanding the shifting range, weight reduction, and greater coordination with the engine. In addition, the era of automated driving, which is just around the corner, requires drivetrain and gear shifting technology research and development on a broader scale than ever.

References

(1) Japan Automobile Dealers Association
(2) MAGNA GETRAG website
(3) JSAE symposium materials, Latest Technology of Drivetrain (2016)