
DRIVETRAIN

1 Introduction

In 2020, new vehicle sales inside and outside Japan were greatly affected by the economic fallout from the novel coronavirus COVID-19 pandemic, falling by 11.5% in Japan (including mini-vehicles) and by 14% on a global basis compared to the previous year. The principal causes of these results included lower demand due to restrictions imposed by governments on inessential trips outside the home and market slowdowns, supply issues, as well as plant closures and production line stoppages to help prevent the spread of infection.

2020 was also a year of events that underlined the growing importance of measures to make vehicles more environmentally friendly, such as signs of a shift toward the introduction of stronger environmental measures after the historic victory of the Democratic Party in the U.S. Presidential election and the Japanese government's declaration of intent to attain carbon neutrality in 2050.

This article summarizes the latest power transmission systems released in the automotive industry in 2020, and also takes a look at the technological trends paving the way for next-generation power transmission systems.

2 Manual Transmission (MT) Trends

2. 1. 6-Speed MT for the Hyundai i30

In February, Hyundai launched an updated version of the i30 (European specifications). The i30 lineup includes a mild hybrid model equipped with a 48 V integrated starter generator (ISG) that combines the 6-speed Intelligent Manual Transmission (iMT) with a new 1.0-liter 3-cylinder turbocharged engine.

The iMT features a by-wire clutch configuration, which helps to reduce fuel consumption by automatically disengaging the engine from the transmission and stopping the engine while coasting. This mechanism has different configurations depending on market requirements, and has been adopted in the Indian market as a clutch

pedal-free manual transmission.

3 Automatic Transmission (AT) Trends

3. 1. Rear-Wheel Drive 9-Speed AT for the Nissan Titan

In January, Nissan launched a refreshed version of its Titan full-sized pickup for North America, equipped with the JR913E 9-speed AT developed by Jatco Ltd. for front-engine, rear-wheel drive models (Fig. 1).

The JR913E is capable of selecting the optimum gear position in accordance with driving conditions to realize a direct and powerful driving performance from start to acceleration at mid-range speeds. It is also able to maintain low engine speeds during high speed cruising to realize excellent fuel efficiency and lower noise. By minimizing the mechanical loss of the oil pump and gears, and varying the internal lubricant flow in accordance with the driving conditions, this transmission achieves high levels of both fuel efficiency and durability.

In addition, by improving the controllability of the solenoid command current inside the control valve and the response of the accelerator operation through activation of the electrical oil pump during shifting, the JR913E helps to realize a driving feel that reflects the intention of the driver more closely.

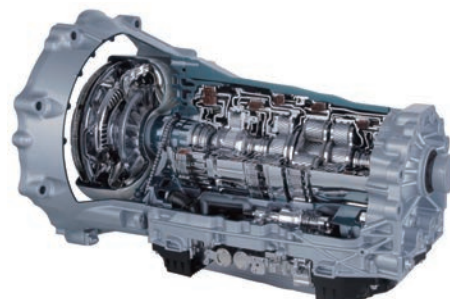


Fig. 1 Cutaway Model of the Jatco JR913E Transmission

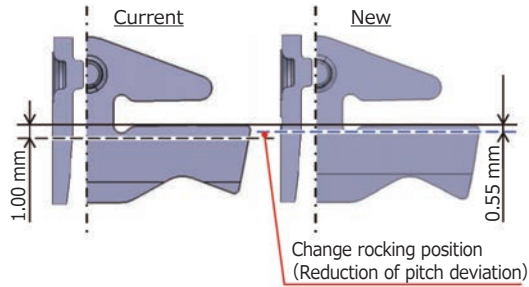


Fig. 2 Comparison of New and Old Elements of Steel CVT Belt Developed by Honda

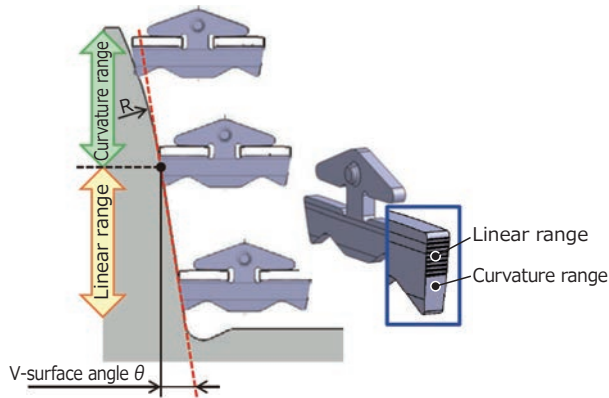


Fig. 3 Complex V-Surface Geometry of Pulley in Honda CVT

4 Continuously Variable Transmission (CVT) Trends

4.1. CVT with Paddle Shifters for the Honda City

In November, Honda launched a hatchback variant of the City in Thailand. The power units combines a 1.0-liter VTEC 3-cylinder turbocharged engine and a 7-speed CVT with paddle shifters.

This new CVT uses a steel belt developed in-house by Honda. The internal sliding resistance of the belt was reduced by 45% by revising the element rocking positions (Fig. 2). In addition, complex V-surface geometry was adopted for the surface of the pulley that contacts the belt, which reduces the holding pressure between the minor diameter (torque transmission) and major diameter (gear ratio determination) (Fig. 3).

Furthermore, the work of the oil pump system was optimized by differentiating between use of the mechanical and electrical oil pumps depending on the pressure and flow rate. The mechanical oil pump is used to realize low-pressure high flow rates for the torque converter and lubrication, while the electrical oil pump realizes the high-pressure low flow rates required for the belt hold-

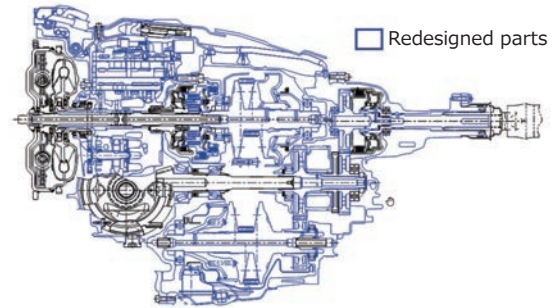


Fig. 4 Main Cross Section of New Subaru Lineartronic CVT

ing force and clutch engagement. This structure raises the power transmission efficiency by 0.7% at the average ratio coverage.

Since the additional electrical oil pump drive consumes power, the system also includes an efficient drive control that acts in accordance with the driving state. The electrical oil pump is driven under conditions requiring certain flow rates and high oil pressure, such as when the vehicle is started, during acceleration from start, when accelerating out of cruising, and so on. This reduces the work of the mechanical pump. In addition, considering its drive power requirements, the control deactivates the electrical oil pump when its loss-reduction effect cannot be utilized, such as during cruising or when accelerating. The electrical oil pump is also used to shorten the delay to re-apply the pulley holding force when the start-stop system disengages.

These modifications enable this CVT to reduce CO₂ emissions by 5.7 g/km compared to the previous model, helping to satisfy the 100 g/km CO₂ emissions requirement of the Thai Eco2 standard.

4.2. Subaru Levorg Lineartronic

In October, Subaru launched the completely redesigned Levorg. Equipped with a newly developed 1.8-liter direct injection turbocharged (DIT) engine with maximum torque of 300 Nm and the Lineartronic CVT, the redesigned Levorg features major upgrades from the first model. Some 80% of the component elements of the CVT were redesigned (Fig. 4). A 22% reduction in total CVT loss was achieved by realizing a ratio coverage of 8.1, the highest for any CVT without an auxiliary transmission, and reducing mechanical losses. Expanding the ratio coverage in this way improved standing start performance. In addition, the specifications of elements such as the oil pump, planetary gears, and the like were changed to greatly reduce noise and to realize high lev-

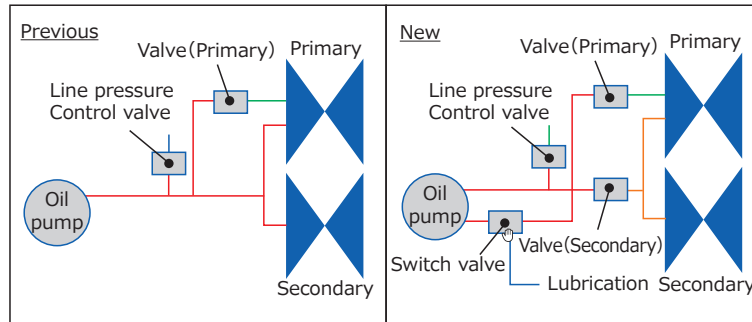


Fig. 5 Hydraulic System of Subaru Lineartronic CVT

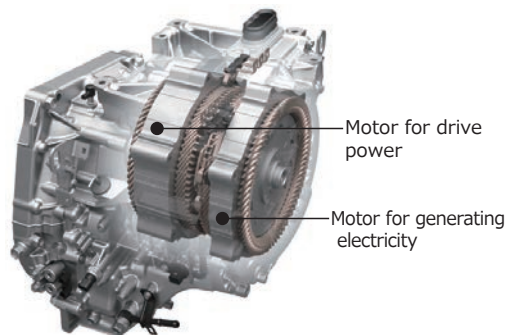


Fig. 6 e:HEV Motor Layout

els of both dynamic feel and environmental performance.

The expanded ratio coverage was achieved by optimizing the chain wrapping diameter without changing the distance between pulley axes, which has a major impact on the internal and external layout of the CVT. This was accomplished by reducing the pulley shaft ratio and applying shot peening to enhance the strength of the shaft, which is affected by the smaller ratio.

An innovative hydraulic function was adopted as part of the process to reduce mechanical loss (Fig. 5). The new structure enables independent control of the line and secondary pressure, which had used a shared control in the previous model. This structure optimized the secondary pressure in operating regions where excess hydraulic pressure beyond the requirements of the variator had been generated.

The number of oil pump discharge ports was increased from one in the previous model to two, resulting in a structure that can be switched depending on the driving situation. During constant speed driving and the like when the supply from the line pressure to each circuit is low, one port is set to low pressure to reduce the load of the oil pump. In addition, noise was reduced further by adopting a vane type oil pump instead of the previous internal tooth type.

5 Drive Systems for Hybrid Vehicles —

5.1. Honda Fit e:HEV

In February, Honda launched a new Fit equipped with a two-motor hybrid system. This new hybrid system is mated to a 1.5-liter Atkinson cycle dual overhead cam (DOHC) i-VTEC engine. Its configuration was commonized with the i-MMD system and completely refined for use in compact class vehicles. The new system is called e:HEV.

The system is equipped with two motors: a motor for drive power (internal) and a motor for generating electricity (external). The motor for drive power is directly connected to the drive shaft and regenerates energy during deceleration. In contrast, the motor for generating electricity is directly connected to the engine. This motor has a simple system and does not act via any complex mechanism or transmission to provide a mix of power (Fig. 6). Including auxiliary equipment, the new hybrid system is more than 20% smaller in both the lateral and longitudinal directions compared to the previous two-motor hybrid system for medium-sized vehicles. Despite being smaller, the new system still produces maximum power of 80 kW and maximum torque of 253 Nm using three-phase AC motors equipped with newly developed compact permanent magnets (PM) with high outputs and high rotational speeds.

The e:HEV system can switch between three drive modes (EV, hybrid, and engine) depending on the driving situation. The system control ensures maximum driving efficiency by taking advantage of the merits of both the motor and the engine.

In daily driving that mainly occurs at constant speeds, the system will select the EV drive mode, in which the vehicle runs on power from the motor alone using electricity from the battery. Since the engine is stopped, the

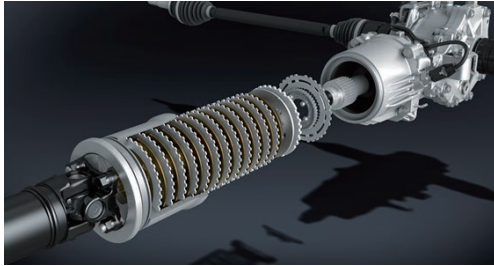


Fig. 7 Electronically Controlled Multi-Plate Clutch of the Toyota GR Yaris

vehicle consumes no gasoline. In this mode, the car drives silently and responsively like an EV. In situations requiring stronger acceleration, the system switches to hybrid mode and the motor drives the vehicle using electricity generated by the engine. This mode generates a linear sound and acceleration in accordance with the vehicle speed. If higher power is required, this is supplied from the battery. Finally, the control switches to engine drive mode at high speeds at which the engine is more efficient. The result is a highly efficient system from low to high speeds.

5. 2. Ford Explorer PHEV

In May, Ford launched a new plug-in hybrid version of the redesigned Explorer for the European market. This model is equipped with a 3.0-liter EcoBoost V6 gasoline engine and a 13.6 kWh lithium-ion battery, and combines a 10-speed AT with torque converter with a 75 KW electric motor between the engine and transmission. The system achieves maximum power of 457 PS (at 5,750 rpm) and maximum torque of 825 NM (at 2,500 rpm).

This new Explorer is also equipped with intelligent all-wheel drive (AWD) and a terrain management system with seven different drive modes. It can also tow up to 2,500 kg. Its cruising range in EV mode is 48 km under the New European Driving Cycle (NEDC) standard, and its CO₂ emissions are 66 g/km.

6 4WD Device Trends

6. 1. GR-Four for the Toyota GR Yaris

In September, Toyota launched the new GR Yaris equipped with an active torque split 4WD system called the GR Four. Featuring a newly developed electronically controlled multi-plate clutch, this system is capable of immediately controlling the torque distribution to the front and rear axles under any road surface conditions (Fig. 7). The system can deliver full traction to the road surface and realizes a direct driving sensation over a wide speed

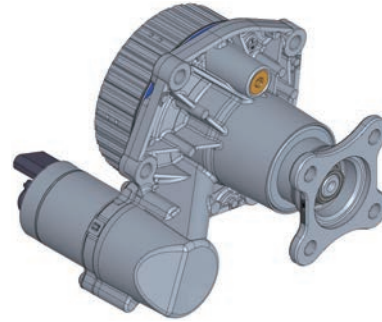


Fig. 8 Electrohydraulically Controlled Clutch of the Nissan Rogue



Fig. 9 Exterior Photograph of Bosch CVT4EV

range from start to high speeds.

The 4WD system uses front and rear Torsen limited slip differentials (LSDs) to distribute the optimum amount of torque instantaneously even on extremely high-G corners, enabling sharply rising acceleration while cornering as well as stable control performance.

Depending on the conditions, the driver can also select control modes with three different front/rear-wheel torque distribution. In Normal mode (60:40), the torque distribution during acceleration is biased toward the front wheels to enable enjoyable and agile performance in ordinary usage scenarios. In Sport mode (30:70), the torque distribution is biased toward the rear wheels, enabling fun-to-drive and brisk handling similar to that of a front-engine, rear-wheel drive vehicle. Track mode (50:50) takes maximum advantage of four-wheel traction for time trials on racetracks and the like.

This sporty 4WD system was developed in-house by Toyota based on wide-ranging know-how obtained as feedback from the World Rally Championship (WRC), and it raises the dynamic performance of the vehicle to even greater heights.

6. 2. Nissan Rogue Hydraulic Coupling

In November, Nissan launched the redesigned Rogue

in North America, combining a 2.5-liter inline 4-cylinder DOHC direct injection engine with the XTronic CVT. The AWD model features a drive mode selector with five drive modes on the center console.

In addition, the intelligent AWD was further advanced with a newly developed electrohydraulically controlled clutch (Fig. 8). This clutch predicts the slippage of the front wheels and, through accurate and rapid torque control, increases the distribution of torque to the rear wheels.

7 Drivetrain Research Trends

As global awareness of environmental issues increases, more EVs are being launched by automakers from compact city models to large sedans and SUVs. At the same time, it is also a fact that powertrain engineers are facing a wide range of challenges to facilitate the wider adoption of EV systems in, for example, vehicles that are driven up steep gradients, sports cars that require a high top speed, vehicles used for towing trailers and caravans, and so on.

The CVT4E continuously variable transmission for EVs was developed by Bosch Netherland (a Dutch subsidiary of Bosch) as one means of addressing these is-

sues.

The CVT4E (Fig. 9) is a compact variable ratio transmission equipped with the company's own push belt technology. It improves the economic efficiency and performance of an electric powertrain while maintaining the smooth and comfortable performance provided by an electric motor. Unlike the mainstream fixed gear stage reduction gears adopted by EVs, the CVT4E has a variable gear ratio that realizes both efficiency and performance, while also lowering noise by reducing the rotation speed of the electric motor. The CVT4E can also increase wheel torque while towing or driving up a gradient, or increase acceleration performance or top speeds on highways by controlling the rotational speed and torque of the motor. The gear ratio is controlled based on the entire system including the inverter, motor, and CVT, thereby enabling the most efficient operating point and helping to improve power consumption efficiency.

Although the torque characteristics of a motor mean that an EV does not absolutely require a transmission, research is likely to continue with the aim of achieving further efficiency gains, reducing size, and enhancing the product appeal of the CVT4E.