CHASSIS, CONTROL SYSTEMS AND EQUIPMENT

1 Introduction

Based on the newly launched models and technologies, the development of chassis and vehicle control technologies in 2015 does not look like just a steady progression from conventional technology. Rather, it feels like the dawn of the introduction of automated driving technology to the market. Given not only the motor shows held last year, but also the never ending stream of news related to automated driving, the topic was impossible to avoid.

Well-established chassis and vehicle control technologies have become the base for adopting automated driving technology. The existing steering, braking, and driving control systems can be said that on a technical level, the system to realize automated driving system is established and only needs the addition of optimal sensor technology and software for automated driving.

Keeping the future of automated driving in mind in that context, chassis and vehicle control technologies give us a glimpse of the kinds of vehicle automakers will offer.

The main new vehicles launched in the market in 2015 are shown separately for the markets in and outside Japan in Table 1 (1) to (3). The diversification of vehicles powered by internal combustion engines (ICEs) to alternatives such as hybrid vehicles (HEVs) or electric vehicles (EVs) has started, but drivetrain layouts and the suspension types are not exhibiting a similar trend. Vehicle control systems are categorized in the following three systems for purposes of this article: suspension control related to the three-dimensional motion of the vehicle body in the direction vertical to the road surface, vehicle dynamics control concerned with planar motion along the road surface, and braking and steering control related directly to the steering system. Technologies made standard equipment in 2015, and technologies already installed in many vehicles, have been omitted for to facilitate reading.

2 Suspension

2. 1. Suspension mechanisms

As noted above, there were no notable changes in the suspension types listed in Table 1, but steady progress can be seen in the streamlining of platform and other structures, as well as the replacement of suspension part materials.

The main types of front suspensions are the strut type for medium-sized or smaller vehicles, and the double wishbone type for larger vehicles. The main types of rear suspensions remains the torsion beam type for compact and smaller vehicles, and the adoption of the double wishbone or multi-link types is expanding in medium-sized or larger vehicles.

The adoption of large scale platforms has been accelerating in all type of vehicles. Cost savings from the commonization and standardization of parts and units has been used for initiatives to improve product appeal.

The Toyota Prius was the first vehicle to use a new platform (TNGA). Improved controllability and ride comfort were realized by lowering the center of gravity greatly, improving the rigidity of the body, and changing the suspension from the previous torsion beam type to a double wishbone type.

A new platform (MLB) was also adopted for the Audi A4, and it achieved a weight reduction exceeding 10 kg over the system as a whole compared to the previous generation by adopting substitute materials (mainly forged aluminum alloys) for suspension parts and streamlining vehicle structures, including the suspension frame.

The adoption of fiber reinforced polymer (FRP) for some springs reflects the trend of using substitute materials in suspension parts.

The GFRP coil spring (Fig. 1) adopted in the Audi A6 Avant Ultra was jointly developed by Sogefi and Audi. The GFRP coil spring has a slightly larger outer diame-

Table 1 List of chassis and vehicle control systems adopted in the main new 2015 vehicles.

Market	Manufacturer/ brand	Truck model name	Category	Drivetrain types (ISS: includes idle stop system)	Drivetrain layouts	Suspension type	Suspension control	Vehicle dynamics control	Brake/steering control
Japan	Daihatsu	Cast	K-Car	ICE	FWD/AWD	Strut/TB, Rigid（AWD）			
	Honda	Legend	Large	HEV	AWD	DW/Multi	Amplitude reactive dampers	Torque vectoring	Agile Handling Assist
		S660	K-Car	ICE	RWD	Strut/Strut			Agile Handling Assist
		Step Wagon	Minivan	ICE	FWD/AWD	Strut/TB			
		Shuttle	Compact MPV	ICE/HEV	FWD/AWD	Strut/TB	Amplitude reactive dampers		Electric servo brake (HEV)
	Mazda	CX-3	Compact SUV	ICE	FWD/AWD	Strut/TB			
		Roadster	Roadstar	ICE	RWD	DW/Multi			
	Subaru	Crossover 7	Mid-size SUV	ICE	FWD/AWD	Strut/DW			
	Suzuki	Every/Wagon	K-Car	ICE	FWD/AWD	Strut/TrailingArm			
		Solio	Compact	ICE	FWD/AWD	Strut/TB, Rigid（AWD）			
	Toyota/ Lexus	Alphard/ Vellfire	Minivan	ICE/HEV	FWD/AWD	Strut/DW			
		Sienta	Compact	ICE/HEV	FWD/AWD	Strut/TB, DW（AWD）			
		Prius	Intermediate	HEV	FWD/AWD	Strut/Multi			
		GS-F	Intermediate	ICE/HEV	RWD/AWD	DW/Multi	ABS vertical G control	Torque vectoring	
Outside Japan	Alfa Romeo	Giulia	Intermediate	ICE	RWD/AWD	DW/Multi		Torque vectoring Active Aero Splitter	
	Audi	A4	Intermediate	ICE	RWD/AWD	Multi/Multi		Torque vectoring	
	BMW	7 Series	Large	ICE/PHEV	RWD/AWD	DW/Multi	Active Roll Stabilization (Navigation) Adaptive Stabilizer	Rear Steering System	Remote parking
		X1	Compact SUV	ICE	RWD/AWD	Strut/Multi			Torque vectoring (brake)
		2 Series Gran Tourer	Compact MPV	ICE	FWD/AWD	Strut/Multi			
	Chevrolet	Tahoe	Large SUV	ICE	RWD/AWD	DW/Rigid	Magnetic Ride Control		
	Chrysler	200	Intermediate	ICE	FWD/AWD	Strut/Multi			
	Elemental	RP1	Roadstar	EV	RWD	DW/DW			
	Ferrari	488GTB	Sports Car	ICE	RWD	DW/Multi			
	Fiat	Tipo	Compact Sedan	ICE	FWD	Strut/TB			
	Ford	S-MAX	Large MPV	ICE	FWD/AWD	Strut/Multi			
		EDGE	Large SUV	ICE	FWD/AWD	Strut/Multi			Adaptive Steering
		F-150	Light Truck	ICE	RWD/AWD	DW/Rigid			
	Honda/ Acura	Pilot	Mid-size SUV	ICE	FWD/AWD	Strut/DW		Torque vectoring（AWD）	
		Civic	Compact	ICE	FWD	Strut/TB			
	Hyundai	ix20	Compact MPV	ICE	FWD	Strut/TB			
		Tucson	Mid-size SUV	ICE	FWD/AWD	Strut/Multi			
	Jaguar	XE	Intermediate	ICE	RWD	DW/Multi			
		XF	Intermediate	ICE	RWD	DW/Multi			
	Kia	Optima	Intermediate	ICE	FWD	Strut/Multi			
		Sorento	Mid-size SUV	ICE	FWD/AWD	Strut/Multi			
	Land Rover	Discovery Sport	Mid-size SUV	ICE	FWD/AWD	Strut/Multi	Hydraulic rebound stop MagneRide variable damper		Torque vectoring (brake)
	Mercedes-Benz	May-Bach S	Large	ICE	RWD/AWD	DW/Multi	Magic Body Control（Sensor） Air Body Control	Cross wind assist	Torque vectoring (brake)
		GLC-Class	Mid-size SUV	ICE	RWD/AWD	DW/Multi		Cross wind assist ESP Trailer Stabilisation	Torque vectoring (brake)
	Nissan/Infiniti	Q30	Compact	ICE	FWD/AWD	Strut/Multi			

Table 1 List of chassis and vehicle control systems adopted in the main new 2015 vehicles (cont.)

Market	Manufacturer/brand	Truck model name	Category	Drivetrain types (ISS: includes idle stop system)	Drivetrain layouts	Suspension type	Suspension control	Vehicle dynamics control	Brake/steering control
Outside Japan	Nissan/Infiniti	Maxima	Intermediate	ICE	FWD	Strut/Multi	Active Ride Control		Active Trace Control Active Engine Brake
		Titan	Light Truck	ICE	RWD/AWD	DW/Rigid			
		Lannia	Compact	ICE	FWD	Strut/TB	Active Ride Control		Active Trace Control Active Engine Brake
	Renault	Espace	Large-MPV	ICE	FWD	Strut/TB			
		Talisman	Large	ICE	FWD	Strut/Semi-Rigid	Active Damping	Four Control (Rear Steering System)	
	Skoda	Superb	Intermediate	ICE	FWD/AWD	Strut/Five Link			
	Tesla	Model-X	Large SUV	EV	AWD	DW/Multi		Advanced Autopilot	Automatic braking at high speed
	Toyota/Lexus	Takoma	Light Truck	ICE	RWD/AWD	DW/Rigid			
	VW	Touran	Comapct MPV	ICE	FWD	Strut/Four Link	Electronic Differential Lock (XDS)		Torque vectoring (brake)

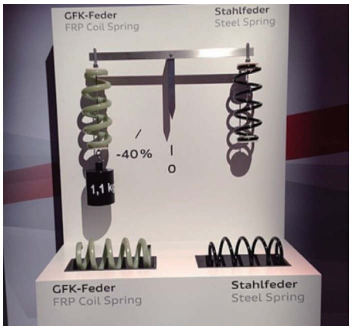

Fig. 1 Audi A6 Avant GFRP Coil Spring(4)

Fig. 2 Volvo XC90 Rear Suspension(5)

ter compared to conventional steel coil springs, but reduces the total weight of the four wheels by 4.4 kg (40%).

A double wishbone rear suspension with a polyurethane FRP transverse leaf spring manufactured by Henkel crossing over (Fig. 2), has been adopted in the Volvo XC90. This reduced weight by 4.5 kg compared to the conventional coil spring, decreased NVH, and improved ride comfort. In addition, the capacity of the trunk has been enlarged due to the elimination of the suspension turret.

2. 2. Suspension controls

There were no notable changes in control devices, but the adoption of electronically controlled variable shock absorbers continues to grow in medium-sized or larger vehicles, and higher performance control resulting from the propagation of technologies such as driving environment recognition is gaining momentum.

Among other types of devices, variable devices for springs and stabilizers continue to be adopted mainly in larger vehicles. For example, the BMW 7 Series uses an air spring with a self-leveling function (capable of changing the vehicle height within a range of -10 mm to +20 mm) and an electronically controlled variable stabilizer.

Incorporating suspension control in integrated vehicle control systems that encompass the steering system and powertrain remains the primary trend in control systems. The use of the navigation and vehicle location information, and of look-ahead information for uneven road surfaces, is becoming more common particularly in suspension control systems for large vehicles.

A system that applies look-ahead to detect the location and size of potholes, controls the suspension and warns the driver based on that information, and also shares it with other vehicles using communication technology, is being developed for the Land Rover.

Highly functional damping force control is also increasingly spreading among medium-sized vehicles such as the Ford Fusion, which uses 2 ms high speed calculations to promptly detect potholes and increase the damping force before the tire drives over the hole, limiting the downward movement of the tire (Fig. 3).

3 Steering

The general adoption of EPS has become even more prominent in the last few years. Hydraulic assist systems have long been mainstream on large body-on-frame vehicles due to the necessity of a large output. However,

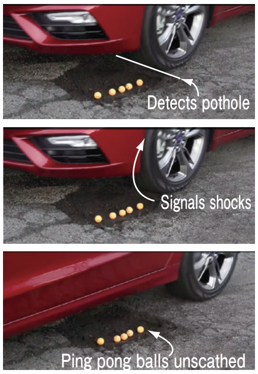

Fig. 3 Pothole Detection Technology. The tire drives over the pothole without falling in it (Ford)(6)

some body-on-frame vehicles now use rack assist EPS with a belt drive system capable of withstanding large outputs.

In the mass production brands of the various automakers, the mainstream steering systems are column-assist EPS in compact and smaller vehicles, and rack-assist EPS in medium-sized and larger vehicles. In contrast, the mainstream system in premium brands is rack-assist EPS for the entire range of compact to high-end vehicles. Automakers choose different assist systems from the standpoints of required output, layout, cost, and steering feel.

Adaptive Steering is a new technology from Ford. It is a system that controls the front steering gear ratio according to vehicle speed. It raises the gear ratio when running at low speeds, reducing the maneuvering required of the driver in tight spaces such as parking spaces, and lowers the gear ratio when running at high speeds, providing control allowing the vehicle to respond smoothly. Vehicle speed sensitive steering systems with a variable gear ratio have already been commercialized by various automakers, but this system is characterized by its mountability. It can be incorporated to the conventional steering system by installing the actuator in the steering wheel.

Recently, the adoption of steering systems with a variable gear ratio corresponding to the vehicle speed and steering angle have become popular, and the adoption of EPS in heavy-duty vehicles is also spreading. Furthermore, the development of steering technologies designed for automated driving will be required, necessitating further initiatives to adapt to large outputs and achieve a high degree of responsiveness.

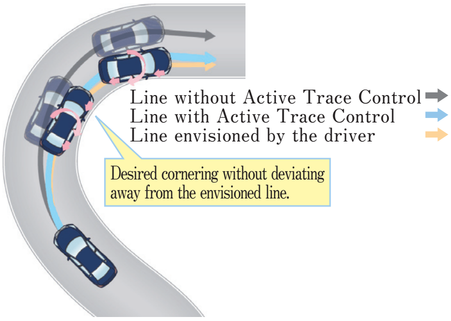

Fig. 4 Operation image of Active Trace Control (Nissan)(7)

4 Brakes

No completely new technologies were introduced for either mechanical brakes or brake-based vehicle dynamics control. However, as shown in Table 1, newly launched technologies are steadily becoming widely adopted. This section covers two such representative technologies.

Hill start assist control keeps the brake engaged even after the brake pedal is released when the vehicle starts going up a hill. This gives the driver time to switch from the brake pedal to the accelerator, and feel confident when starting off on a hill. Although it is not a new technology, it has been spreading to more and more mini-vehicles in recent years, and is now found in almost all models, including the Suzuki Alto, the Daihatsu Cast and Move, and the Honda S660. It can be said that this function is becoming standard equipment on all vehicles.

Nissan's Active Trace Control is a system adopted in the Maxima and Lannia that controls the yaw moment to enable fun and comfortable driving (Fig. 4). Applying automatic braking to all four wheels prevents the vehicle from deviating away from the ideal line envisioned by the driver and stabilizes vehicle posture. This allows drivers to confidently concentrate on driving even in situations where they need to control the accelerator, brake, and steering wheel in a coordinated manner, and enjoy smooth cornering.

Such yaw moment control technology using the brake has also been adopted by automakers other than Nissan. For example, Honda has introduced Agile Handling Assist in the Legend and S660, while the Discovery Sport features the Land Rover Torque Vectoring by Braking system. In 2015, the Honda S660 was especially noteworthy. In the past, such vehicle dynamics control systems were primarily adopted in luxury vehicles. However, the S660 is the first mini-vehicle in the world equipped with

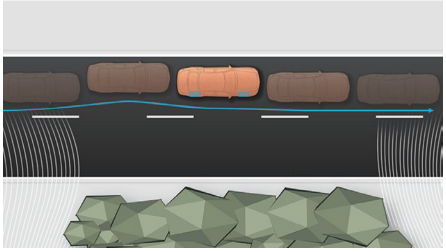

Fig. 5 Operation image of Crosswind Assist (Mercedes Benz)(8)

Fig. 6 BMW 7 Series display remote key(9)

Agile Handling Assist which, notwithstanding the fact that the S660 is a sporty vehicle, can be described as a landmark. The increasing adoption of these technologies will remain a point of interest in 2016.

5 Other Vehicle Controls

Table 1 lists various control mechanisms other than the brake-based vehicle dynamics control introduced in Section 4 that have started to become more prevalent as integrated vehicle control technologies such as by-wire technology has evolved.

Crosswind Assist, which is found in the Mercedes Benz GL-Class (Fig. 5), is a vehicle dynamics control system to help prevent unintended deviations in heavy-duty vehicles such as minivans when they are hit by a crosswind. The brake is used to actuate control, but the EPS sensor is used to detect the crosswind and realize the integrated control of the steering and brake systems.

Another integrated control system adopted in various vehicles is the lane keeping assist function, which typifies the integrated control of the camera, brakes, and steering. The camera recognizes the white line on the road surface and applies a yaw moment away from the white line commensurate with the deviation of the vehicle. It is installed in various vehicles to ensure they remain in their traffic lane. Mercedes-Benz uses an adaptation of this technology known as Road Surface Scan, which controls the coil springs on the four wheels to compensate for uneven road surfaces detected by the camera and improve ride comfort.

In addition to the widespread adoption of integrated control to help reduce the driving load such as those described above, there is steady progress in the development of vehicle dynamics control for driving pleasure. Torque vectoring exemplifies such vehicle dynamics control. Automakers are working to develop various technologies to improve cornering performance by controlling the longitudinal and lateral distribution of the torque generated by the powertrain components such as the engine. The Nissan Active Trace Control and Honda Agile Handling Assist systems fall in the category of the primarily brake-based yaw moment control systems introduced in Section 4. For its part, Audi realizes optimized torque distribution with the quattro integrated control system, which combines AWD differential gears and ESC, and has been installed in the A4. Meanwhile, the torque vectoring technology (Sport Hybrid SH-AMD) adopted in the Honda Legend improves the cornering performance by adjusting the regenerative energy from the motors mounted on the right and left rear wheels.

The future of vehicle dynamics control cannot be discussed without mentioning advances in automated driving. Although it is difficult to compare automated driving technologies directly since there are different definitions of its level, 2015 was a year in which automakers started to apply the expression “automated driving” to their products.

Automakers have introduced automatic parking systems that allow the driver to identify a parking space while sitting in the vehicle. The system introduced in the BMW 7 Series makes it possible to reverse the vehicle and stop the engine remotely using a key with a touchscreen (Fig. 6).

Until now, vehicle dynamics control was a function involving technologies such as the aforementioned torque vectoring that promoted the joy of driving to drivers, and automakers will now apply those technologies to automated driving technology. Autonomous vehicles such as the Tesla Model S will soon be seen driving around town.

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