CHASSIS, CONTROL SYSTEMS AND EQUIPMENT

1 Introduction

Recently, the social demand to reduce the environmental impact of vehicles while also enhancing safety has been increasing. In addition, as the transition to autonomous driving is becoming a real possibility, automakers are locked into continuous competition to develop these technologies and to put them into practical use.

England and France addressed environmental friendliness in the summer of 2017 by announcing that they will prohibit the sales of new gasoline and diesel vehicles by 2040. Since then, government-led efforts to shift from internal combustion engine to Electric Vehicle (EV) have been accelerating, prompting one automaker after the other to announce plans to introduce EVs.

Active safety technology and other aspects of safety performance are being reflected in the revision of the Advanced Emergency Braking Systems (AEBS) international standard (UN R131) is currently taking place to expand its scope from only heavy-duty vehicles such as trucks and buses to include passenger vehicles, as well as to add regulations on tests for pedestrian protection. In parallel, the Japanese government established a national certification system for AEBS performance.

One measure to prevent traffic accidents involving elderly drivers promotes vehicles equipped with features such as automatic braking systems and functions that suppress acceleration when the accelerator is depressed by mistake, as safe driving support vehicles under the nicknames Safety Support Car and Safety Support Car S to raise awareness and encourage the spread of such vehicles.

Requirements concerning autonomous driving at speeds of 10 km/h or less (automatic parking) and lane-keeping assistance while holding the steering wheel have been added to the international standard on steering equipment (UN R79), and also included in the safety regulations in Japan. Phase 6 of the Advanced Safety Vehicle (ASV) Promotion Project (FY 2016 to FY 2020) similarly advocates the study of concrete technologies focused on autonomous driving and the popularization of such technologies. Vehicles equipped with level 2 autonomous driving functions have been released, and public road demonstration tests for higher levels of autonomous driving will also be conducted.

This article describes the chassis and vehicle control device trends focusing on the new models and technology released in 2017 in the context of these social trends. The main new models launched in and outside Japan in 2017 are shown separately in Table 1[(1)]. However, technologies such as Electronic Stability Control (ESC) that are mandatory in various countries, and warning functions that are part of active safety technologies, have been omitted.

2 Suspension

2. 1. Base Suspensions

As shown in Table 1, the suspension types of new models in 2017 follow recent trends and present nothing new. The main types of front suspension continue to be the strut type for medium-sized or smaller vehicles, and the double wishbone type for larger vehicles.

The recent trend of standardizing suspension types due to automakers adopting large-scale platforms is continuing. Examples from 2017 include the Toyota Prius PHV and Camry, which use the Toyota New Global Architecture (TNGA), the Subaru XV built on the Subaru Global Platform (SGP), the Volvo XC60 which adopts the Scalable Product Architecture (SPA), and the Volkswagen Polo which uses Modulare Quer Baukasten (MQB). The Subaru SGP achieves both straight line driving in accordance with driver intent through increased vehicle body and component part rigidity, and pleasant ride comfort and stability through decreased unpleasant vibration and noise[(2)].

Table 1 Chassis and vehicle control systems of new vehicles launched in 2017

Market	Manufacturer/brand	Name of vehicle model	Drivetrain type	Drive system	Suspension type Front/Rear ( ): suspension for AWD layout	Vehicle control systems
Japan	Suzuki	XBEE	MHEV	FF/AWD	Strut/TBA (3 link)	Cruise Control/Hill Hold Control/Dual Sensor Brake Support/Erroneous Start Prevention/Back-up Brake Support/Rear Erroneous Start Prevention
		Spacia	MHEV	FF/AWD	Strut/TBA (3 link)	Hill Hold Control/Dual Sensor Brake Support/Erroneous Start Prevention/Back-up Brake Support/Rear Erroneous Start Prevention
		Swift Sport	ICE	FF	Strut/TBA	Hill Hold Control/Dual Sensor Brake Support/Erroneous Start Prevention/Lane Departure Prevention Function
		Wagon R	ICE/ MHEV	FF/AWD	Strut/TBA (3 link)	Hill Hold Control/Dual Sensor Brake Support/Erroneous Start Prevention
		Swift	ICE/MHEV/HEV	FF/AWD	Strut/TBA (TBA)	Hill Hold Control/Dual Sensor Brake Support/Erroneous Start Prevention
	Subaru	XV	ICE	AWD	Strut/DW	Cruise Control with Full-speed Traffic Following Function/Constant Speed Cruise Control
	Daihatsu	Mira e:S	ICE	FF/AWD	Strut/TBA (3 link)	Smart Assist Ⅲ (Crash-avoidance Support Braking Function (Vehicles/Pedestrians)/ Erroneous Start Prevention (Forward/Rear))/Hill Hold System
	Toyota	Camry	HEV	FF	Strut/DW	Toyota Safety Sense P (Pre-collision Safety System (Collision Avoidance Assist Type with Pedestrian Detection)/Lane Departure Alert (with Steering Control)/Radar Cruise Control (with Full-speed Following Function))/Intelligent Clearance Sonar (with Rear Cross-Traffic Braking)/S-VSC (Steering-assisted Vehicle Stability Control)/Drive-start Control/Hill Start Assist Control/Vehicle Speed Sensitive Type EPS
		Prius PHV	PHEV	FF	Strut/DW	Toyota Safety Sense P (Pre-collision Safety System (Collision Avoidance Assist Type with Pedestrian Detection)/Lane Departure Alert (with Steering Control)/Radar Cruise Control (with Full-speed Following Function))/S-VSC (Steering-assisted Vehicle Stability Control)/Drive-start Control/Hill Start Assist Control/Vehicle Speed Sensitive Type EPS
	Nissan	Leaf	EV	FF	Strut/TBA	Emergency Assist for Pedal Misapplication/ProPILOT (automated driving technology designed for highway use in single-lane traffic)/ProPILOT Park/Intelligent LI (Lane Departure Prevention Assist System)/ Intelligent Ride Control (Vehicle Vibration Suppression System)/Hill Start Assist/Cruise Control/Vehicle Speed Sensitive Type EPS
	Honda	N-Box	ICE	FF/AWD	Strut/TBA (TBA)	Honda SENSING (Collision Mitigation Braking System/Erroneous Start Prevention/Rear Erroneous Start Prevention/Pedestrian Collision Mitigation Steering System/Road Departure Mitigation System/Adaptive Cruise Control/Lane Keeping Assist System
		Civic	ICE	FF	Strut/Multi-Link	Honda SENSING (Collision Mitigation Braking System/Adaptive Cruise Control with Low-Speed Following/Lane Keeping Assist System/Road Departure Mitigation System)/Hill Start Assist Function/Agile Handling Assist
	Mazda	CX-8	ICE	FF/AWD	Strut/Multi-Link	Hill Launch Assist/Advanced Smart City Brake Support (Forward/Reverse) & Pre-collision Throttle Management (Start/Reverse)/Smart Brake Support/Mazda Radar Cruise Control (with Full-speed Following Function)
		CX-5	ICE	FF/AWD	Strut/Multi-Link	Hill Launch Assist/Advanced Smart City Brake Support (Forward/Reverse) & Pre-collision Throttle Management (Start/Reverse)/Smart Brake Support/Mazda Radar Cruise Control (with Full-speed Following Function)
	Lexus	LS	ICE/HEV	FR/AWD	Multi-Link/Multi-Link	Lexus Safety System + A (Pre-Collision Safety System (with Active Steering Assist)/Lexus CoDrive (All-Speed Dynamic Radar Cruise Control) & Lane Tracing Assist & Lane Change Assist/Driver Emergency Stop Assist (coordinated with Lane Tracing Assist)/VDIM (with Integrated Active Steering Control) + Lexus Dynamic Handling System/Parking Support Brakes/Hill-start Assist Control/Brake Hold
		LC	ICE/HEV	FR	Multi-Link/Multi-Link	Lexus Safety System + (Pre-Collision Safety System (Collision Avoidance Assist Type with Pedestrian Detection)/ All-Speed Dynamic Radar Cruise Control/Lane Keeping Assist/VDIM (with Integrated Active Steering Control)/Lexus Dynamic Handling System/Drive-Start Control/Hill-start Assist Control/Brake Hold
Outside Japan	Audi	Q5	ICE	AWD	DW/DW	Audi Pre Sense City (Automatic Braking)/Adaptive Cruise Control/Traffic Jam Assist (Vehicle Distance Maintenance)/Active Lane Assist/Side Assist/Turn Assist/Park Assist/Exit Warning
		A8	ICE	AWD	Air suspension	Audi Pre Sense Plus (Automatic Braking)/Adaptive Cruise Control/Active Lane Assist/Park Assist
	BMW	M5	ICE/HEV	AWD	DW/Multi-Link	Active Cruise Control/Steering and Lane Control Assistant/Active Side Collision Protection
		X3	ICE	AWD	Strut/Multi-Link	Hill Descent Control/Active Cruise Control/Steering and Lane Control Assistant/Active Side Collision Protection
		MINI Countryman	ICE/PHEV	FF/AWD	Strut/Multi-Link	Parking Assistant
		5 Series Touring	ICE	FR/AWD	DW/Air suspension	Active Cruise Control/Steering and Lane Control Assistant/Active Side Collision Protection

Table 1 Chassis and vehicle control systems of new vehicles launched in 2017 (cont.)

Market	Manufacturer/brand	Name of vehicle model	Drivetrain type	Drive system	Suspension type Front/Rear ( ): suspension for AWD layout	Vehicle control systems
Outside Japan	Mercedes-Benz	CLS	ICE	FR/AWD	Strut/Multi-Link	DISTRONIC PLUS (with Steering Assist)/Brake Assist PLUS (with Cross-Traffic Assist)/PRE-SAFE Brake (with Pedestrian Detection)/Rear-end Collision Warning System with Damage Mitigation Brake/Active Blind Spot Assist/Active Lane Keeping Assist
	Citroën	C3	ICE	FF	Strut/TBA	Active Safety Brake/Hill Start Assist
	Ford	Lincoln Navigator	ICE	FR/AWD	Multi-Link/Multi-Link	Active Park Assist/Adaptive Cruise Control/Pre-Collision Assist with Pedestrian Detection (Automatic Braking)/Hill Descent Control
	Honda	Accord	ICE/HEV	FF	Strut/Multi-Link	Honda SENSING (Adaptive Cruise Control with Low-Speed Follow/Lane Keeping Assist System/Collision Mitigation Braking System)
	Peugeot	5008	ICE	FF	Strut/TBA	Active City Brake/Active Cruise Control/Active Lane Keeping Assistance
	Porsche	Cayenne	ICE	AWD	Multi-Link/Multi-Link	Electronic Air Suspension
	Renault	Mégane GT	ICE	FF	Strut/TBA	Emergency Brake Assist (Active Brake)/Easy Park Assist/Multi-Sense/Hill Start Assist
	Tesla Motors	Model 3	EV	RR/AWD	Multi-Link/Multi-Link	Autopilot/Automatic Braking
	Volkswagen	Polo	ICE	FF	Strut/TBA	Front Assist (Semi-automomous Driving)/City Emergency Braking (Pedestrian-aware Collision Mitigation Braking System)/Park Assist/Adaptive Cruise Control
		Arteon	ICE	AWD	Strut/Multi-Link	Adaptive Cruise Control/Park Distance Control (with Collision Mitigation Braking Function Forward/Backward)/Rear Traffic Alert (Warning Backward, Collision Mitigation Braking Function)
	Volvo	XC40	ICE	AWD	Strut/Multi-Link	Semi-autonomous Drive Function (Pilot Assist)/City Safety/Run-off Road Mitigation/Run-off Road Protection
		XC60	ICE/PHEV	AWD	DW/Multi-Link	Adaptive Cruise Control/City Safety (Automatic Braking)/Oncoming Lane Mitigation (Oncoming Lane Departure Prevention Assist)/Pilot Assist (Lane-keeping Assistance Function)/Blind Spot Information System with Steer Assist and Cross Traffic Alert/Lane Change Merge Aid/Lane Keeping Aid

2. 2. Suspension Controls

There were no major changes in suspension control devices. In line with recent trends, electronically controlled damping force adjustment mechanisms and air suspensions have been adopted in high-class sedans and sports vehicles, and settings suited to the individual drive modes are available. Suspensions that use magnetic fluid continue to be adopted on a subset of luxury vehicles outside Japan.

Along with the vehicle height adjustment function that can be switched between normal and high settings, the electronically controlled air suspension been adopted in the Lexus LS features an access mode function that adjusts the vehicle height automatically to make it easier to get in and out of the vehicle[3].

Citroën vehicles are being equipped with a mechanism called Progressive Hydraulic Cushions, which is a function that smooths bumps and rebounds using two hydraulic stops set respectively on the compression and rebound sides, to form a structure in which the springs and hydraulic stops dissipate the energy from large road inputs. This improves comfort by avoiding the impact at the end of travel that occurs with conventional stops[4].

In the area of occupant comfort, Bose, which is widely known for its electromagnetic suspension system, refined its suspension seating system. Bose announced further advances to the single axis (vertical direction) motion control system used in vehicles such as heavy-duty trucks with a switch to an active multi-axis motion design that adds roll control. This system relies on moving the seat in opposite phase to the vibrations to cancel them[5].

3 Steering

The mainstream Electric Power Steering (EPS) systems, which have widely replaced hydraulic power steering due to their superior fuel efficiency, remain unchanged, with column-assist EPS used in compact and smaller vehicles, and rack-assist EPS in medium-sized and larger vehicles. The rack thrust in rack assist EPS becomes progressively more powerful in single pinion, dual pinion, and belt drive EPS, and belt drive systems with even higher output are also being developed. In contrast, development to improve fuel efficiency by downsizing and reducing the energy consumption of column assist EPS is also underway. Ongoing development targeting even greater fuel efficiency is anticipated for light- and medium-duty vehicles, which are subject to

strict expectations in that respect, while more powerful rack thrust is predicted to remain the main demand in the development of heavy-duty vehicles.

In addition, technologies featuring both steering stability at high speeds, and good handling and a smaller turning radius at low speeds are also becoming more prevalent. One example is the adoption of the variable gear ratio mechanism used in vehicles such as the Audi A4. This mechanism changes the gear ratio at high and low speeds to achieve both steering stability at high speed and good handling at low speeds.

Another example is the four-wheel steering systems introduced in a few models toward the end of the 1980s, which have recently become more common in mainly luxury vehicles, such as the Audi A7, but can also be found in the Renault Mégane GT C-segment model, for example. The system in the Mégane GT uses control to set the in-phase at speeds of 60 km/h or higher, and the counter-phase at speeds below 60 km/h, achieving both stable cornering and good handling in situations such as parking[6].

EPS represents an essential system in the context of the rapid progress automobile and parts manufacturers have been making in driving safety support and autonomous driving technologies. The increased motor capacity resulting from adapting to the needs of driving support and autonomous driving are enabling greater active steering control which is expected to eventually be applied to steering functions used for lane keeping, lane changes, or automatic parking.

4 Brakes

The spread of ESC actuators and other brake pressurization devices has expanded the role of the brakes beyond just decelerating the vehicle to active use as a means of controlling various vehicle dynamics and behavior.

Brake-based traction control and stability control have long been used to ensure vehicle driving stability, and a technology called torque vectoring, which uses braking force as a way to transfer load to the wheels to improve cornering performance, has also become commercially available on some models.

In addition, collision mitigation braking systems are being used in a variety of cases, as exemplified by systems such as Honda SENSING, Suzuki Dual Sensor Brake Support, Daihatsu Smart Assist Ⅲ, which respond to pedestrians as well as vehicles, have been extended to mini-vehicles, and are gaining more advanced functions.

One example is post-collision braking systems, widely adopted in vehicles ranging from mass-market vehicles such as the Volkswagen Polo to luxury vehicles, which automatically apply deceleration to prevent secondary injuries caused the vehicle entering the oncoming lane or multiple collisions, in the event of a rear-end or other collision[7]. Another example are the rear-end collision warning with collision mitigation braking systems installed in Mercedes-Benz and Volvo luxury models, which aim to reduce injuries to occupants and avoid pile-ups by applying brake pressure just before the rear-end collision while simultaneously warning (on-screen and hazard lamps) both drivers when there is a risk of the vehicle getting rear-ended[8]. In Japan, the application of collision mitigation braking systems is being extended to a broad variety of situations other than just before or after an accident, or of whether the vehicle is stopped or in motion, as illustrated by the function in Lexus vehicles that detects abnormal driver states and stops the vehicle.

Electric Parking Brakes (EPB) are no longer limited to luxury or hybrid vehicles, but have also been made standard equipment on some mini-vehicle models. The systems do not simply replace human operation with electric switch, but include an automatic parking function that activates itself in accordance with engine stops or other situations, the already widespread hill-start assist function that facilitates starts on a slope, and even a downhill assist function in some vehicles such as SUVs. Technology applied in the field of brakes is exhibiting dynamic changes, including replacing functions in which actuator heat generation limited activation time if only hydraulic devices are used.

5 Vehicle Controls

Although vehicle controls are quite varied, they can be broadly categorized into those that prevent accidents beforehand, and those that enhance comfort.

Representative vehicle controls for preventing accidents beforehand are the collision mitigation braking system which detects an object ahead and applies the brakes, or the erroneous start prevention function that prevents accidents caused by pressing the wrong pedal. Moreover, the number of vehicles controls that operate the steering wheel to prevent collisions due to the vehicle swerving, lane deviations, or lane changes have also

increased.

The Honda Lane Keeping Assist System (LKAS) detects the lane using a monocular camera and provides steering assist to keep the vehicle in the center of the lane. Volvo Blind Spot Information System with Steer Assist and Rear Collision Warning detects the other vehicles approaching from behind using millimeter wave radars in the left and right sides of the rear bumper during a lane change or unintended lane deviation. If the system determines that there is a high risk of collision, it automatically directs the steering to move the vehicle back into its original lane. BMW Active Side Collision Protection uses four sensors mounted on the front, rear, right, and left sides of the body to monitor traffic conditions at the sides of the vehicle. When the risk of side collision increases, such as when the vehicle in an adjacent lane moves into the lane of the vehicle, the system intervenes to steer the vehicle away from the approaching vehicle without leaving the current lane to help avoid a collision[9].

The improvements in the recognition, decision-making, and operation brought to these functions are expected to transfer to fully autonomous driving. Current systems corresponding to autonomous driving level 2 include the Nissan ProPILOT, and Volvo Pilot Assist which, on roads such as highways, provide lane keeping steering assistance while maintaining an appropriate following distance from the preceding vehicle or driving at a set speed if the vehicle is in the lead.

The Lexus LS offers the Driver Emergency Stop Assist system, which decelerates and eventually stops the vehicle within its lane while alerting other road users in the vicinity through the hazard lamps and the horn, unlocks the doors and also a rescue request upon detecting an abnormal driver state, thus applying emergency measures if the condition of the driver changes suddenly.

There are vehicle controls for enhancing comfort that do not rely on stabilizing the vehicle when cornering to improve ride comfort.

The Nissan Leaf has adopted Intelligent Ride Control, which suppresses unpleasant vibrations when passing over bumps on the road by controlling the engine and brakes, and provides pleasant ride comfort[10]. The Mercedes-Benz Magic Body Control detects small road surface irregularities via a stereo camera and independently controls the hydraulic units of each wheel to suppress rolling and pitching and maintain a level posture like that on a smooth road under various conditions. It also achieves exhilarating cornering while allowing occupants to remain stably seated by tilting the vehicle towards the inside of the corner when cornering.

Vehicle controls for preventing accidents beforehand are anticipated to evolve even further to continue to respond to the needs for safety performance and autonomous driving, and to be installed in various vehicle models rather than only in luxury vehicles. Similarly, vehicle controls for enhancing comfort are also likely to develop even further from the standpoint of enhancing product appeal.

References

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