ELECTRIC EQUIPMENT

1 Introduction

Automobiles are expected to offer improved performance and more advanced functionality as a safe and comfortable means of transportation that also realizes a sustainable society. The electric equipment in the vehicle is playing a larger and larger role in making vehicles more environmentally friendly, safer, and more comfortable.

On the environmental front, the use of electricity as the means of propulsion in vehicles, such as electric vehicles (EV) and hybrid electric vehicles (HEV), is becoming more prevalent to reduce the amount of CO_2 emissions. The announcements in 2017 by France, the UK, and other countries that they adopt policies to prohibit the sale of new gasoline and diesel vehicles by the year 2040 attracted quite a lot of attention. Such policy incentives are helping advance efforts toward electrification. The development of new powertrains, such as those for fuel cell vehicles (FCVs) is also being actively pursued. Nevertheless, conventional internal combustion engine (ICE) vehicles will remain predominant for the foreseeable future, and ongoing efforts are being made to further increase the efficiency of these engines. Addressing the ever increasing electrical power demands of on-board systems requires alternators with high output, as well as control over the electric power generated via a system that works in cooperation with the vehicle. Starters are not only expected to become lighter and more compact to improve fuel economy and mountability, but are also required to satisfy strict durability requirements to cope with the increased frequency of engine starts. In addition, achieving even greater engine efficiency is increasing the need for spark plugs with highly reliable ignitability even under conditions that make combustion difficult, such as high levels of exhaust gas recirculation (EGR) and lean-burn systems. The debate about eliminating Freon from automobile air conditioning systems is intensifying in response to the global movement to prevent further depletion of the ozone layer.

In the field of automotive safety, rapid progress is being made in the areas of automated driving (AD) and advanced driver assistance systems (ADAS). In the case of AD, multiplexing is required to ensure safety in the event of a functional failure. At the same time, the displays and instrument panel providing the interface between people and automobiles are becoming increasingly important. In conjunction with infrastructure improvements, the speed and capacity of multiplex communication systems is being raised to enable the exchange of information with sources outside the vehicle. Connecting vehicles to external information sources offers great convenience, but also presents a growing security risk that is prompting the development of various security technologies. Furthermore, efforts are being made to spread awareness of automatic braking and devices that suppress acceleration when the accelerator is depressed by mistake and further disseminate them.

In terms of comfort, on-board information systems and audio systems are continuing to evolve. The evolution and popularization of smartphones and other mobile devices is making connecting with these terminals an important factor.

Electric equipment in automobiles will continue to contribute to meeting various consumer needs in terms of environmental friendliness, safety, and comfort.

2 Technological Trends in Automotive Electric Equipment

2. 1. Electric Equipment for Charging Systems

The adoption of stricter fuel economy regulations around the world is stepping up the pace of adaptation to electrification, and making it necessary for alternators to provide the following functions.

(a) Higher output and efficiency to meet the increased electrical power demand resulting from the electrification of components.

(b) An energy regeneration system that employs optimal charging control in accordance with the driving state of the vehicle.

(c) Replacing the diode rectifiers with an inverter to assist the engine in providing drive power to the wheels.

Technologies proposed to realize these functions include the use of high-density stator windings (adoption of rectangular wires), mounting magnets on the rotor to compensate for leakage flux, designing regulators as single-chip integrated circuits (IC), improving the cooling performance of the power diodes, and reducing heat loss. Furthermore, the adoption of bidirectional digital communication interfaces such as pulse width modification (PWM) signals and Local Interconnect Network (LIN) communication for the control system has enabled the optimization of the amount of power generated, as well as energy recovery during deceleration.

Start-stop systems are becoming standard equipment, and belt starter generator (BSG) or integrated starter generator (ISG) systems that extend alternator functionality to providing drive power in addition to generating electricity have been developed. This additional function has made quiet engine restarting and the provision of drive-power assistance to the engine possible.

Furthermore, 48-volt electric power supply systems are becoming commercially available in preparation for upcoming vehicle electrification. Consequently, conventional belt driven alternators are starting to be replaced with three-phase AC interior permanent magnet (IPM) motors directly connected to the engine output shaft. Further advances in automobile electrification are expected to result in a shift toward integrating alternators and starters developed specifically for starting functions into AC motors.

2. 2. Electric Equipment for Starting Systems

The growing number of auxiliary devices around the engine aimed at improving the fuel economy, along with the higher density of the engine compartment due to the expansion of the interior cabin space for passengers is creating a need for even smaller and lighter starters. Therefore, compact, high-torque gear-reduction starters with a built-in deceleration mechanism are now often equipped in ordinary passenger vehicles. In addition, high-performance ferrite magnets and higher built-in reduction ratios are being used to make motors even lighter and more compact. At the same time, efforts to improve fuel economy have led to a higher number of vehicles equipped with engine start-stop systems and systems that turn the engine off even before the vehicle comes to a complete stop. Since such systems involve more engine stops and restarts than in the past, they must be capable of withstanding far more frequent use than existing starters. In addition, ongoing expectations for these systems will not be limited to extending their service life, but also, with respect to comfort and responsiveness, encompass shortening the engine start-up time and reducing start-up noise.

2. 3. Electric Equipment for Ignition Systems

The ignition system generally consists of ignition coils for each cylinder, spark plugs, and angle sensors used to detect the rotational angle of the crankshaft and camshaft. As fuel consumption and emissions regulations worldwide become more stringent, next-generation automobiles, such as those relying on electricity as their primary source of drive power, are increasingly being developed and commercialized. Not all of these vehicles will be electric vehicles (EVs), however, and the anticipated increase in the number of vehicles equipped with engines, such as HEVs and plug-in HEVs (PHEVs), still makes it necessary to further raise engine fuel efficiency. The use higher compression ratios to attain greater efficiency, and the need for ignition in environments not conducive to combustion, such as high exhaust gas recirculation (EGR) and lean burn conditions is prompting the increased use of higher energy ignition systems. Consequently, there has been a shift toward the use of plug top ignition coils due to their superior mounting flexibility and the efficient design of their magnetic circuits. At the same time, the application of a higher energy system accelerates wear on the spark plugs whose durability must therefore also be improved. To improve ignitability in combustion-resistant environments, ways to improve this durability are being examined in conjunction with a review of the spark plug shape, and the reduction of the diameter of the discharge electrodes. Digital output sensors, which feature excellent signal detection accuracy and signal control, are easy to mount, directly detect the crankshaft and camshaft angles, and attach directly to the engine, have become mainstream. It has become increasingly common to mount angle sensors on both camshafts as variable valve timing mechanisms have been adopted for both the air intake and exhaust systems. Research on a new ignition system to further improve ignitability in combustion-resistant environments and achieve enhanced combustion efficiency is also underway. Electric equipment for the ignition system is expected to continue to play a critical role as a key component in achieving cleaner exhaust emissions.

2.4. HVAC Equipment

Innovations in the HVAC systems in automobiles are required to respond to the major changes in both refrigerant regulations concerning powertrain technologies in the context of addressing environmental issues. At the 28th Meeting of the Parties to the Montreal Protocol (in October 2016), the developed nations agreed to reduce the production of hydrofluorocarbons (HFC) by 85% by 2036 (compared to 2011-2013 levels). The pace of initiatives to make the world free of Freon and strengthen the related regulations has also stepped up. For example, the European Directive on mobile air conditioning systems (MACs) states that the use of refrigerants with a global warming potential (GWP) value of 150 or higher shall be regulated for all new passenger cars sold in the European market starting on January 1, 2017. Automotive air conditioners that use CO_2 as a refrigerant have also been developed and their installation in mass-produced vehicles has begun.

In conventional ICE vehicles the interior passenger compartment is heated using the waste heat emitted from the engine. However, heating in EVs, which do not have an engine, requires a separate heat source. Positive temperature coefficient (PTC) heaters and heat pump air conditioners are being studied as potential heat sources for use in EVs. The PTC heater is a system with a simple structure that converts electrical energy into thermal energy via resistance heating, but it presents the problem of consuming a large amount of power, resulting in a large negative impact on EV cruising range. In contrast, heat pump air conditioners consume less power than PTC heaters and have little impact on cruising range but have their own problems, namely the large size of the equipment and reduced heating effectiveness in cold regions. Methods to recover waste heat from inverters, motors, and batteries, as well as ways of improving the performance of the heat pump cycle itself are being developed to address these issues.

2.5. Steering

Stricter fuel economy regulations around the world, along with the growing adoption of driving support systems have led to the installation of electric power steering (EPS) systems on nearly 100% of passenger and other vehicles. In addition, the strengthening of safety requirements in preparation for automated driving systems and for compliance with ISO 26262 (Functional safety) require the EPS system to have a redundant configuration that allows continued steering in the event of a failure. Consequently, the development of systems with multiplexed microcontrollers, sensors, and other components is accelerating. Optimal design technologies that keep output loss low at the time of a failure are becoming a key technology to ensure adequate output under those circumstances. The adoption of steer-by-wire (SBW) systems derived from this multiplexing system concept is also becoming feasible. In the future automated driving level 3 or higher will be covered by steering systems in which the steering wheel in the vehicle and the rack in the engine compartment are not connected mechanically, which are likely to become mainstream. Furthermore, the development of a truck platooning system for commercial vehicles on highways is intensifying the pace of the development of steering systems that add electric functions to the conventional hydraulic power steering for heavy-duty trucks that require high output.

2.6. Displays and Instrument Panels

The role of displays and instrument panels as the interface between people and automobiles is becoming increasingly important. This is particularly true for automobiles below automated driving level 4, in which it is essential for the vehicle to pass on driving support information and alerts about the state of the vehicle to the driver, and new technologies such as an ultra-large head-up display (HUD) and driver monitoring systems to assist with steering are being developed to project and display various kinds of information. Although the display devices that make up a HUD are predominantly thin film transistor (TFT) liquid crystal panels, laser scanning micro-electro-mechanical (MEMs) projection systems that use digital light processing (DLP) to display information with greater precision and reduce overall power consumption are being considered as replacements.

In addition, augmented reality (AR) displays enabling information to be presented to the driver in a more easily recognizable way such as by superimposing it over the scenery in front of the vehicle, are being developed. Displays and instrument panels that can foster closer communication between automobiles and people have become a requirement.

2. 7. Multiplex Communication Systems

The rapid advances in automated driving, connected vehicles, and electrification is paralleled by the increasing speed of 4G, 5G, Wi-Fi and other wireless mobile communication systems. The amount of data transmitted within the vehicle, including sensor, map, and external information, is increasing at an explosive rate, making it urgent to increase the speed and capacity of multiplex communication systems. Furthermore, cybersecurity measures for vehicles have recently become more important, with star and bus configurations centered around a central gateway used as the mainstream network topologies, in which multiple layers provide message authentication and other forms of secure communication, as well as protection against external attacks. In this context, the standard controller area network (CAN) vehicle communication system that connects together the vehicle control, body and information systems is gradually being replaced by the higher speed and higher capacity CAN with Flexible Data Rate (CAN-FD) protocol. In addition, the on-board version of the widely used Ethernet technology is now entering the stage of practical use starting at 100 Mbs, and speeds of 1 Gbps and higher are also being investigated.

2. 8. Vehicle-Mounted Information Systems

The number of vehicle navigation systems shipped in Japan in 2017 was 5.82 million units, an increase of 4.5% over the previous year. The majority of the navigation system market, some 99% of the total, is made up of flash memory-based products (according to the Japan Electronics and Information Technology Industries Association (JEITA)). Advanced functions, such as high-resolution, large displays coordinated with safety functions that make use of camera images continue to become more sophisticated, while audio systems with display screens offering optional navigation functions are increasingly popular, especially in markets outside Japan. In addition, the spread of smartphones and advances in mobile communications have allowed vehicles to connect to the Internet, leading to the intensification of initiatives directed at connected cars that create new value. Connected cars either feature an embedded communication module as standard on-board equipment, or relying on linking with the user's smartphone. Technologies allowing on-board information systems to connect with things such as external real-time information, telematics services that use vehicle information, and smartphone applications are also being commercialized. Moving forward, entirely new markets are expected to be created by V2X technologies, which will support safer driving by enabling communication between vehicles, from vehicles to traffic infrastructure, and from vehicles to people, as well as by over the air (OTA) technologies that allow the software in on-board equipment to be updated via the internet. Despite their convenience, the various means of communicating with external sources acquired by vehicles also present higher the threat of hacking and underscore the importance of cybersecurity, a situation that is expected to spark intensified efforts to enhance vehicle security.

2. 9. Audio Systems

The number of on-board CD player systems shipped in Japan in 2017 was 1.988 million units, a decrease of 9% compared to the previous year. This continues the downward trend from 2016 when 2.18 million units were shipped, which was a decrease of 16% compared to 2015, according to data from JEITA. In contrast, the demand for portable information devices with functions that enable the operation of smartphones and portable music players from on-board devices continues to rise. Currently, Bluetooth is the main form of wireless communication used to connect to these portable information devices, and inductive charging technologies to supply electrical power are predicted to become more widespread. Digital radio broadcasting continues to grow in popularity in North America. In Europe, efforts to implement digital audio broadcasting (DAB) are being stepped up as various national governments promote the transition to digital radio, and the installation rate of digital broadcasting receivers is expected to continue to rise. Audio systems with display screens are now often used to provide driver support when parking. In addition, with interaction with smartphones enabling the display and playing of Internet radio content, traffic information, and video data these functions will certainly continue to evolve and diversify further. These audio systems are now often equipped on more affordable, mass-production vehicles as well, creating expectations that their share of the vehicle infotainment device market will continue to increase.

2. 10. Safety Devices

The number of traffic accident fatalities in Japan in 2017 was 3,694 people, which was 210 less than the previous year. This was also the smallest number of fatalities since 1948, the earliest year for which such statistics still exist (according to a summary from the National Police

Agency). This also represents a decrease to about one fifth that of the largest number, which was 16,765 people in 1970. Prior to 2017 the lowest number of traffic fatalities recorded in Japan was 3,790 people in 1949, marking the first time in 68 years that this record has been broken. According to the National Police Agency, elderly people aged 65 or older accounted for 2,020 of the total number of traffic fatalities in 2017, a decrease of 118 people compared to the previous year. However, this also accounts for 54.7% of all such fatalities, keeping that percentage at a stubbornly high level. According to an analysis of the traffic accident fatalities that had occurred as of the end of November 2017, the largest number of such fatalities occurred amongst pedestrians who were walking on or near the road, who accounted for 1,171 fatalities, a decrease of 12 people (1.0%) compared to the same period during the previous year. The next largest number of fatalities was amongst people riding in automobiles at 1,106 people, a decrease of 102 people (8.4%) compared to the previous year. This was followed by 436 people killed in traffic accidents while riding bicycles, representing a decrease of 12 people (2.7%) compared to the previous year.

Under these circumstances, one measure enacted by the Japanese government to prevent traffic accidents involving elderly drivers consists of giving the Safety Support Car S nickname to vehicles equipped with both automatic braking systems and devices that suppress acceleration when the accelerator is depressed by mistake (safe driving support vehicles) and the Safety Support Car nickname to vehicles equipped with just automatic braking systems, and establishing public-private partnerships to raise awareness and encourage the spread of those vehicles. The Safety Support Car S vehicles, which are especially recommended for elderly drivers because they have the automatic braking system and the mistaken acceleration suppression device, among other features, are classified into three types: wide, basic plus, and basic, depending on the automatic braking system and other accompanying functions. By the same token, the Safety Support Car is recommended for all drivers because it is equipped with an automatic braking system.

Every automobile manufacturer is expected to cooperate with suppliers to develop and sell vehicles equipped with automatic braking and various other advanced safety technologies to support safe driving by all drivers.