Electric Equipment

1 Introduction

The social and environmental conditions affecting vehicles are continuing to change rapidly. Automakers are facing rising demands to enhance the environmental friendliness, safety, convenience, and comfort of vehicles to create suitable means of transportation capable of achieving a safer and more secure sustainable society. Current changes facing the industry include the global spread of motorization trends to emerging nations, declining birth rates, aging populations, and the diversification of user needs. To face up to these challenges, automakers must construct new services and systems, and advance the development of means of mobility and transportation. Electric equipment will play a major role in meeting these demands, with the innovation of related technology and the promotion of development being particularly important.

From the standpoint of environmental friendliness, the enactment of more stringent fuel economy standards to help save energy and to reduce fossil fuel consumption and greenhouse gas emissions, in combination with growing global demand for fossil fuels has led to a rise in crude oil prices. As a result, there has been an increasing shift to the use of motors, as expressed by the popularity of electric and hybrid vehicles.

However, the conventional internal combustion engine remains the mainstream vehicle power plant and active efforts are under way to further improve the fuel efficiency of these engines. Development of new ways to improve the thermal efficiency of engines, such as through the use of high compression ratios and turbocharging, is also progressing. Consequently, the required performance of ignition systems is also becoming more diverse. Many manufacturers are also starting to equip vehicles with idling stop systems (ISS) and regenerative brakes. This is promoting the further evolution of key electrical components equipment of these systems, such as starters and alternators, which have been used in vehicles for many years. In addition, the adoption of electric power steering systems and high-efficiency heating, ventilation and air conditioning (HVAC) systems are also increasing to reduce the load on the engine.

In the safety field, mandatory seatbelt use and the spread of airbags have helped to alleviate injuries suffered during collisions. Increased adoption of devices that improve driving stability, such as anti-lock braking systems and electronic stability control, has helped to reduce the number of traffic accident fatalities and injuries each year. The adoption of active safety systems that monitor areas around the vehicle using radar and cameras will become increasingly important to further enhance accident prevention. It is likely that more advanced technology will be developed to help improve the recognition performance of these systems. There have been a series of major accidents attributed to driver drowsiness in recent years. Systems are being commercialized to help prevent dangerous situations such as these using vehicle-mounted cameras to monitor the state of the driver. It is hoped that these systems will help to prevent accidents in the future.

Related to convenience and comfort, the degree to which information from both inside and outside the vehicle can be utilized is an important factor in the level of convenience and comfort provided to vehicle occupants. Following recent trends, vehicle navigation devices have been equipped with more and more functions. Consequently, these systems have played a central role as vehicle-mounted information systems. However, in recent years, the importance of fixed, preprogrammed functions has been replaced by systems with the capability to quickly keep up with changes in information services provided around the world. In particular, the rapid spread in the use of smart phones has led to a corresponding increase in demand for in-vehicle devices that can connect to smart phones and utilize the latest cloudbased information services in vehicles. Furthermore, devices that can be used without having to be looked at directly and easily visible displays are important so that all of this information can be obtained safely while driving. This has promoted advances in more natural voice operation and the display of information by head-up display (HUD) systems, which are effective means of reducing the time required to move the driver's field of view from one location to another.

2 Technological Trends in Automotive Electric Equipment

2. 1. Electric equipment for charging systems

Standards and regulations related to fuel economy and emissions are growing more and more stringent. At the same time, users are also demanding continuous improvements in vehicle comfort. One countermeasure to meet these demands that is becoming more common is ISS, which limit the wasteful consumption of fuel by stopping the engine while the vehicle is parked or waiting at traffic signals. The development of ISS is interconnected with various automotive systems, such as those related to power supply management like the engine starter and alternator, the brakes, and air conditioning.

In the case of the regenerative braking systems, lithium-ion batteries have been adopted to enable the collection of even more energy. The alternators that are used in these systems have been re-development for higher efficiency with finely tuned controls through power width modulation (PWM) signal and local interconnect network (LIN) communication. An effective way to boost the efficiency of the alternator itself is to switch to high-frequency drive by adopting multiple poles, and to reduce the resulting losses. There are two types of alternator losses: magnetic loss due to the switch to high frequencies (i.e., stator core iron loss) and electrical winding loss (copper loss). Since lower alternator losses can be achieved by reducing the iron loss of the core material, each electrical equipment manufacturer is developing technology to achieve this aim.

2. 2. Electric equipment for starting systems

The amount of auxiliary systems installed around the engine is increasing as part of measures to improve vehicle fuel efficiency. As a result, the development of smaller and lighter starters continues to be an important way to improve installation capabilities.

Generally, starters operate by extending a pinion gear on engine start and engaging with a ring gear on the engine side. Power from the starter motor is then passed through the pinion gear to start the engine.

Conventional starters use an interlocked structure for extending the pinion gear and applying the current to rotate the motor. These starters cannot begin operation to re-start the engine while the ring gear is rotating due to inertia after the vehicle has stopped. This creates a maximum delay time of approximately 1.5 seconds before the starter can re-start the engine.

The latest starters resolve this with controls that change in accordance with the engine speed. At high engine speeds, current is applied to the motor to increase the rotation of the pinion gear. The pinion gear is then extended when it reaches a speed similar to the ring gear. At low engine speeds, the pinion gear is extended first and then current is applied to the motor. As a result, the engine can be re-started while it is still rotating, ensuring a smooth start-off feeling.

2. 3. Electric equipment for ignition systems

Important requirements for ignition control systems include the development of more sophisticated controls and easier installation by reducing size and weight. These measures will allow the ignition system to satisfy the need for improved fuel efficiency and cleaner exhaust emissions, and to respond to the requirements of higher efficiency and smaller engines. Such ignition control systems are generally composed of an ignition coil and spark plug located at each cylinder, and angle sensors that are located on the crankshaft and camshaft.

Until recently, more and more vehicles used spark plug hole-type ignition coils, in which the winding portion of the coil is housed within the spark plug holes of the engine. However, in recent years, the use of plug top-type ignition coils has increased because the efficiency of the magnetic circuits is higher and there is a higher degree of freedom for the high voltage path.

Recently ignition coils have been developed with two types of output performance: standard ignition coils, and high-energy ignition coils compatible with measures to enhance ignitability under difficult conditions due to adoption of direction injection (DI) in gasoline engines, heavy exhaust gas recirculation (EGR), and lean-burn combustion.

Spark plugs are also becoming smaller in diameter as conventional screw diameter M14 plugs have given way to M12 plugs. Although these are currently the mainstream size of plug, M10 diameter plugs are also starting to be adopted in more engines. In addition, the diameter of discharge electrodes is also being reduced, and manufacturers are developing electrode chip materials with excellent wear resistance to improve ignition efficiency with the smaller diameter discharge electrodes.

Angle sensors have excellent signal detection precision, signal control, and are easy to install. Digital output sensors that can be mounted directly on the engine and that can detect the angle directly from the crankshaft and camshaft have become the mainstream type of sensors. In recent years, angle sensors with a direction of rotation detection function have been adopted to improve engine restart performance after idling stop. Recent angle sensors can also accurately detect the angle when the crankshaft has returned in the opposite direction after the engine stops.

In addition, as the development of next-generation engines with even greater thermal efficiency continues, new ignition systems that use multiple ignition, high-frequency ignition, and low-temperature plasma ignition, are also being developed. The aim of these technologies is to ensure combustion under difficult in-cylinder conditions such as heavy EGR and lean-burn combustion. Electric equipment for ignition systems will likely continue to be important in the future as a key technology for enabling the realization of more environmentally friendly engines.

2.4. HVAC equipment

Powertrain trends are changing greatly in response to growing awareness of environmental problems. For a similar reason, major changes are also taking place in HVAC systems for compliance with new regulations about refrigerants.

Following the growing trend of vehicles installed with ISS, HVAC systems with cold storage evaporators are being commercialized that store cold air while the engine is running, which is then used to cool the cabin when the engine is stopped. Electric vehicles (EVs) conventionally used electric heaters instead of the engine as the heat source for the HVAC system. However, the large electric load of this method has an adverse effect on the cruising range of the vehicle. Although these can be replaced by heat pump systems with high heating efficiency, one issue to be resolved is ensuring heating performance in extremely low temperature regions.

The conventional mainstream refrigerant HFC-134a was adopted as a replacement for certain specified chlorofluorocarbons (CFCs). However, this refrigerant also has a large global warming potential (GWP) and the European Union (EU) issued a European Directive in January 2013 that made it mandatory for all automotive HVAC systems to use a refrigerant with a GWP of less than 150. As a result, a new refrigerant called HFO-1234yf began to be adopted. However, it has been suggested that HFO-1234yf will produce a toxic gas if ignited in an accident. Therefore, there are also initiatives to switch to the use of CO_2 as a refrigerant due to its lower environmental impact. However, CO_2 refrigerant must be used under high pressures, which presents difficult engineering issues and concerns that it will greatly increase the weight and cost of the HVAC system.

2.5. Steering

Electric power steering (EPS) offers a 3 to 5% improvement in fuel efficiency compared to conventional hydraulic power steering (HPS). The mainstream form of EPS in the market is the steering column assist type due to its advantages in terms of installation and cost. This system has become widespread, mainly in Japanese and European compact vehicles. However, as technology to improve steering feel and increase system power becomes more advanced, and as the electrification of the entire vehicle starts to accelerate, EPS systems have also started to be used on medium- and large-size vehicles. The introduction of more stringent fuel economy standards in the European and U.S. markets after 2010 has prompted predictions that rack-assist type EPS systems with excellent handling, vibration, noise, and power performance would begin to replace HPS on large and luxury vehicles as well. Demand for EPS mainly in low-price compact vehicles in emerging markets has also increased dramatically, creating a global market with huge potential for expansion. The number of remaining electro-hydraulic power steering (EHPS) systems is highly likely to fall in the long-term, replaced by EPS systems with excellent fuel efficiency and controllability.

The component parts of EPS systems are also changing. For example, efforts are under way to reduce size and weight by integrating the motor and ECU structures, and to reduce the amount of rare earth used in the motor. In addition, steering systems that ensure safety and continue assisting steering operations after a malfunction are being developed through adding redundancies and multiplexing, including of sensing parts. This trend is being rapidly promoted in compliance with the

Functional Safety Standard (ISO 26262) that was officially published in 2011.

The installation of EPS also allows integration with other vehicle electrical systems. When used with cameras and radar, this may result in the expansion of sophisticated driver support systems, parking assist systems, and systems that support evasive maneuvers in an emergency in combination with image recognition technology. Following this trend, higher performance sensors are also likely to be developed for these systems.

2. 6. Displays and instrument panels

Conventionally, the main function of the instrument panel has been to provide gauges such as the speedometer that communicate information about the vehicle.

However, instrument panels are now expected to have greater display functionality to accommodate the recent increase in fuel economy-related displays designed to increase awareness of environmentally friendly driving and the need to indicate information related to safety equipment such as collision mitigation brakes. Furthermore, as autonomous driving becomes a critical topic, the importance of the instrument panel as a device to connect the car and driver will only increase.

Recent rules and regulations include the passing of the hotly debated rear-view requirements in North America, which should result in more vehicles installed with back guide monitor systems. In addition, the future of international standardization activities is also being discussed related to the electrification of rear-view mirrors to support the indirect field of view of the driver. It is likely that the first display-based mirror systems will be adopted in mass-production cars in the next few years. HUDs have been adopted throughout the luxury vehicle segment. In addition to developments for expanding the display sizes and creating full-color displays, HUDs may also start to be adopted in standard vehicle classes. Higher quality center displays are also being developed to match user's expectations in the era of smart phones and tablets. The result of this trend should be finer and larger vehicle-mounted units that are easier to use with touch-operation capabilities and other innovations. Plans to develop vehicle-mounted units that use smart phone functions have been announced by consumer-related companies and greater connectivity is expected between these units and smart phones in the future.

2. 7. Multiplex communication systems

Although the number of stand-alone automotive electronic devices is increasing for compliance with environmentally friendly CO_2 emissions regulations, achieve advanced driver assistance systems (ADAS) for safety, and connect with smart phones for more convenience, the amount of communication between these systems is also growing rapidly. There are also growing security concerns when using such multiplex systems. In response, research is under way to examine the configuration of multiplex systems and to examine the introduction of new communication protocols.

Central gateways, in which several communication buses are arranged in a star-like configuration around a central terminal, are gradually becoming the mainstream network structure. The increase in electronic devices will be handled by increasing the number of communication buses connected to the gateway. From the standpoint of security, externally connected diagnostic device systems are gradually changing so that only trustworthy data is swapped via the gateway without directly connecting with the buses used for in-vehicle communication.

The controller area network (CAN) and FlexRay are the principle types of mainline communication. However, new entries in this field such as flexible data rate CAN (CAN FD) and Ethernet are also gaining prominence. CAN FD is an expanded version of existing CAN systems that is capable of boosting throughput by speeding up data regions only. Discussions are currently under way at the International Organization for Standardization (ISO) to standardize this technology. As it is a lower-cost system than FlexRay, studies are making progress. Ethernet is being introduced for the diagnostics over internet protocol (DoIP), a next-generation standard for vehicle-mounted cameras and diagnostics systems. Studies are examining if it can also be applied to entertainment and control systems.

In addition to ECU-to-ECU communication, the feasibility of communication between ECUs and sensors or actuators is also being examined. In addition to conventional LIN communication, protocols such as the clock extension peripheral interface (CXPI), digital serial interface (DSI), peripheral sensor interface 5 (PSI5), and single edge nibble transmission (SENT) are regarded as potential communication options.

2. 8. Vehicle-mounted information systems

The number of vehicle navigation systems shipped in Japan in 2013 was 5,470,000 units, 97.8% of the previious year (data according to the Japan Electronics and Information Technology Industries Association (JEITA)). The shift away from hard disc drives (HDDs) to the use of flash memory as a storage medium continued in 2013, and flash memory now accounts for approximately 73% of the total. In addition, 2013 saw further progress in trends to achieve connectivity between portable devices such as smart phones and vehicle-mounted devices. In addition to higher communication speeds, the use of portable devices with display and audio units has become the norm.

The transition from 3G to the 4G long term evolution (LTE) protocol is continuing. In 2013, the Global Mobile Suppliers Association announced that LTE had achieved a penetration rate of 21% in Japan.

As of December 2013, a total of 40,710,000 on-board Vehicle Information and Communication System (VICS) devices for traffic information had been shipped (data according to the Vehicle Information and Communication System Center).

The ITS World Congress held in Tokyo in October 2013 featured demonstrations of more sophisticated information provision systems (such as next-generation VICS, systems that provide information in the event of a natural disaster, cloud-connected systems, and ITS spot systems) on public roads. It is hoped these systems will find practical applications in the future.

2. 9. Audio systems

In 2013, the number of vehicle CD players that were shipped in Japan declined slightly to 3,211,000 units (95.8% of the previous year), continuing the downward trend of recent years that is probably partially due to the spread of smart phones (data: JEITA).

In addition to CDs, data is increasingly being inputted into vehicle audio systems through hard-wired USB slot connections, universal serial bus (USB) devices, iPods, iPhones, and Android-compatible smart phones. The transmission of music data from smart phones via wireless Bluetooth functions is also increasing. More audio systems can be controlled directly from smart phones, increasing user convenience.

Broadcast systems include analog AM and FM radio in Japan. However, hybrid digital (HD) radio is popular in the U.S. and Mexico, and digital audio broadcasts (DAB) are popular in Europe, South Korea, and Australia. It is likely that more vehicles for emerging markets will be equipped with functions to receive digital broadcasts. Even in Japan, digital broadcasts using V-low multimedia broadcasting technology are being examined and future trends are being monitored closely.

Vehicle navigation systems and display/audio systems capable of connecting with smart phones are becoming more widespread, following the recent growth in smart phone ownership and increases in communication speeds. Interconnectivity with smart phones allows information received by the smart phone (such as internet radio stations like Pandora, Aha Radio, and iHeart Radio) and music to be inputted into the navigation or display/audio system. The playing or displaying of information in this way is likely to expand in the future. The adoption of display/audio systems will probably advance in popular vehicles, making smart phone interconnectivity a key function for audio systems in the future.

The evolution of audio and communication systems in the consumer electronics (CE) field will affect the functions of vehicle-mounted audio systems, and there is a good chance that audio systems will be developed to provide new experiences to users.

2. 10. Safety devices

In 2013, the number of traffic accident fatalities in Japan was 4,373 people and the number of people injured in a traffic accident was 781,494. The number of traffic accident fatalities has now declined for 13 consecutive years and is now less than 30% of the peak number (16,765 people in 1970). Furthermore, the number of traffic accidents and injuries has also fallen for 9 consecutive years. However, the year-on-year decline in traffic accident casualties has slowed to a trickle and the number of elderly fatalities rose for the first time in 12 years since 2012. The number of accidents involving heavy duty vehicles on expressways still remains high, tragically costing the lives of far too many people. As a result, the state of traffic accidents in Japan remains critical.

Given these circumstances, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is proceeding with plans to make it mandatory for all large-sized vehicles to be equipped with a collision mitigation brake system. These systems are already mandatory for large trucks (over 22 tons) and large buses (over 12 tons) and will be gradually extended to apply to medium-size trucks (over 8 tons) from 2018, as well as small trucks (over 3.5 tons) and small buses (12 tons or less) from 2019. Government initiatives included giving cabinet approval to the following items in June 2013: (1) the Japan

Revitalization Strategy, (2) a declaration to be the world's most advanced IT nation, and (3) the Comprehensive Strategy on Science, Technology and Innovation. The targets of each initiative include the following: (1) development of and infrastructure establishment for safe driving support and autonomous driving systems, (2) promotion of the development and practical adoption of sophisticated driver support technologies and autonomous driving systems, and (3) zero traffic accident fatalities with the aim of achieving the safest and most comfortable road traffic system in the world. Toyota Motor Corporation, Nissan Motor Co., Ltd., and Honda Motor Co., Ltd. participated in establishing these initiatives and have already held demonstrations of autonomous driving technology on public roads attended by Prime Minister Abe. These efforts have had the effect of vitalizing research and development into autonomous driving.