Electric Equipment

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1 Introduction

In order for automobiles to continue to be a safe and comfortable means of transportation for people around the world, it is the responsibility of the automotive industry to continue minimizing the factors that hinder the realization of a low-carbon, recycling-oriented, and safe and secure society. There is also demand for the ability to access a variety of information and services while being in vehicles as a part of an advanced information society, as well as for vehicles that can be driven safely and easily by the elderly in an aging society. Since electric equipment plays a large role in meeting these kinds of societal demands, improving the performance of this equipment and developing new functions are essential.

Increasing environmental awareness has led to more stringent regulations concerning vehicle fuel economy to help save energy and to reduce fossil fuel consumption and greenhouse gas emissions. However, at the same time, the global demand for fossil fuels has continued to grow, resulting in a rise in crude oil prices. As a result, there has been an increasing shift to the use of electric motors, as expressed by the popularization of electric and hybrid vehicles. However, the conventional combustion engine still accounts for the majority of motors used to power vehicles in the world and there are active efforts 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 and regenerative braking systems. This is promoting the further evolution of key electrical components and 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 is also increasing to reduce the load on the engine.

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 cloud-based information services while being 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 within the dashboard instrument panel.

Advances in electric equipment have also accelerated improvements in vehicle safety. Changes, such as 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 preventive safety systems that monitor areas around the vehicle using radar and cameras will become increasingly important to further enhance accident prevention. These include collision avoidance systems that can automatically stop the vehicle. Increasing the number of vehicles that use these systems will eventually reduce costs and may contribute to a reduction in traffic accidents, including those involving pedestrians.

2 Technological Trends in Automotive Electric Equipment

2. 1. Electric equipment for charging systems

Idling stop systems and regenerative braking systems are increasingly being adopted to help comply with more stringent fuel economy regulations. Conventionally, the technological requirements for the electric equipment in charging systems have been small size, high output, high efficiency, and low noise. However, new products have been introduced into the market in recent years that can also meet the functional demands of new systems.

Idling stop systems have adopted innovations such as a belt-driven motor generator that is an inverter built-in alternator. These systems can provide drive power as well as simply generate electricity, allowing quiet and rapid restarting of the engine. Furthermore, systems have been adopted that use this drive power to assist the output of the engine for improving fuel efficiency.

In the case of the regenerative braking systems, electric double-layer capacitors and lithium ion batteries are being used for storage devices to recoup even more energy. The alternators that are used in these systems are equipped with a regulator that makes it possible for the host controller to carry out fine control through pulse width modulation (PWM) signal communication or digital bidirectional communication.

Concerning the basic power generation performance of the alternator, to improve its power output density, stator winding density has been increased, magnets have been installed on the rotor to compensate for magnetic flux leakage, and the cooling performance of the rectifier and regulator has been improved. In addition, in order to reduce noise, the transformation of the stator winding into a 5-phase or 6-phase multiphase device, compared to conventional 3-phase stator winding, is also being promoted.

2. 2. Electric equipment for starting systems

There are continued demands to develop smaller and lighter starters to satisfy the requirements for improved fuel efficiency and easier installation. In general, gear-reduction starters equipped with an internal planetary reduction gear mechanism and starters that use a permanent magnet for the magnetic field are most often used to meet these needs. However, even larger reduction ratios and high performance ferrite magnets are being adopted in an effort to achieve even further reductions in size and weight.

The idling stop systems that have been adopted on many buses and delivery vehicles are now starting to be used in general passenger vehicles on a larger scale, and this trend is expected to grow rapidly in the future. However, in this system, the engine is automatically stopped and restarted repeatedly each time that the vehicle stops, such as when waiting at a stop light. This means that the number of times that the starter is used will increase significantly in comparison to a conventional vehicle without an idling stop system. As a result, the starter must have more durability number of times. In addition, there are also increasing demands to reduce the noise that is generated when the vehicle is started and to shorten the start-up time to reduce the time lag that occurs upon engine restart and vehicle acceleration. Furthermore, technologies that allow the engine to be stopped before the vehicle comes to a complete rest and that allow the engine to be restarted quickly if the driver has a change of mind immediately after the engine stops are being developed in order to increase the operation opportunity of idling stop.

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. Current control systems are generally composed of angle sensors that are located on the crankshaft and camshaft and ignition coils that are located on each engine cylinder.

These 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, some idling stop systems have adopted angle sensors with a direction of rotation detection function to improve engine restart performance after idling stop. These sensors are able to accurately detect the angle even when the crankshaft has returned in the opposite direction after the engine stops.

The adoption of variable valve timing mechanisms and direct injection systems is being promoted to help make engines as efficient as possible. The cylinder heads in the engine are also becoming more complex. At the same time, the overall size of the engine is being reduced and efforts are being made to ensure that there is space above the engine to help reduce the impact suffered by a pedestrian in the event of a collision. Therefore, the space available for mounting the electric equipment of the ignition system is becoming extremely small and mounting restrictions are becoming more severe. In addition, there are also increasing demands to increase the energy of the ignition coils as engines now often feature a higher compression ratio, higher turbocharging pressure, and high levels of exhaust gas recirculation (EGR).

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.

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 used more often. In addition, the diameter of the electrodes is also being reduced and spark plugs with a microchip attached to the electrode are also being developed to improve ignition efficiency.

The ignition system can play a role in achieving even more precise combustion control. Therefore, an ion current detection system that detects the state of combustion by using the spark plug as a probe to detect the ions produced by combustion has been put into practical use. 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. 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

Major changes in automotive HVAC equipment are taking place as the awareness of environmental problems increases. HVAC equipment with electric compressors and cold air storage functions are increasingly being adopted to ensure cooling performance when the engine is stopped. This trend is accompanying the spread and popularization of idling stop systems for improving vehicle fuel efficiency. In addition, the improved efficiency of engines and motors has decreased the amount of discharge heat that can be utilized, resulting in insufficient heating capacity. Especially in the case of electric vehicles, there is so little heat discharged by the motor that precious electric energy must be used in the winter to provide heat. This has the effect of reducing the cruising range of the vehicle. Heating systems that use a heat pump and heaters in the seats and steering wheels that provide heat directly to the vehicle occupants have been commercialized to address this issue.

The use of certain specified chlorofluorocarbons (CFCs) with a large ozone depletion potential (ODP) was prohibited from being used in vehicle HVAC systems. CFCs were replaced with an alternative called HFC-134a, but this also has a large global warming potential (GWP) and became a target for reduction in the Kyoto Protocol. In Europe, where environmental consciousness is especially high, a European Directive was issued in January 2013 that makes it mandatory for all new vehicles to use a new refrigerant called HFO-1234yf. 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, leading to concerns that this will greatly increase the weight and cost of the HVAC system.

2.5. Steering

It has been a quarter of a century since electric power steering (EPS) was first adopted in light vehicles in 1988. During that time, EPS has come to be used in almost all vehicles from standard-sized cars to pickup trucks. In addition to improved fuel efficiency, there are several other major factors contributing to the growth of EPS use in vehicles. Reducing the size and weight of EPS systems improved mountability and steering feel. Advances in the development of EPS technology have also increased system power.

In 2012, global vehicle production reached 82 million vehicles, continuing a trend of 5% growth from the previous year. The number of vehicles equipped with EPS also grew in conjunction with the increase in the number of vehicles in emerging markets, where compact cars are most common. In addition, the shift to higher output EPS in developed countries increased the use of EPS in standard-sized cars. This increased the number of vehicles equipped with EPS by 10% compared to the previous year, even higher than the increase in overall vehicle production. This growth is likely to continue in the future.

Development trends for EPS system components include the integration of motors and controllers, and technology to reduce the amount of rare earth materials in motor magnets. In addition, the development of EPS systems that guarantee safety after a malfunction by the addition of redundancies and multiplexing is also being promoted in compliance with the Functional Safety Standard (ISO 26262) that was officially published in November 2011.

The scope of steering controls is also expanding to include improvements to vehicle convenience, such as parking assist, as well as improvements to vehicle stability and safety through active steering control and the coordinated control with stability control systems. These types of advanced EPS systems are being optimized while evolving greater safety, security, and comfort.

2.6. Displays and instrument panels

Repeated advances in the visibility, safety, and operability of the instrument panel have been achieved even while achieving superior design as part of the vehicle's interior.

It is now common for the dashboard to be equipped with small displays that show information such as driving distance and fuel economy. Additional advances such as the use of color and large-sized screens in the information displays have been implemented to provide even more information to the driver. Full-screen LCD meters which replace the whole dashboard with LCD displays have even started to be adopted on some luxury vehicles.

Demands are also increasing for center displays that can show high-quality video images. Further advancements in larger sized screens with high resolutions and high definition are likely to occur to keep up with the display specifications of portable devices, such as smart phones and tablet computers. In the future, the dashboard meters and center display may become integrated into a single large panel.

In addition, the projection of driving support information onto the front windshield in a head-up display (HUD) is also starting to become more common. The development of even larger screens is being promoted. The use of displays with curved surfaces, which place a greater emphasis on design, is also being studied, which means that research and development into technologies such as curved LCDs and rear projection displays is progressing.

Vehicle-mounted touch screens will probably continue to shift from conventional resistive touch types to multi-touch capacitive type screens. Furthermore, it should become possible to operate certain vehicle functions from a portable device via wireless linkages or other means in the future.

2.7. Multiplex communication systems

Various types of sensors, actuators, and human-machine interfaces are being mounted on vehicles to increase environmentally friendliness by reducing CO_2 emissions, and to improve safety and comfort. In addition to increasing the number of parts that run on electricity, the scale and complexity of multiplex communication systems is also advancing. Since these systems are used for different purposes in control, body, and information systems, the adoption of various different industry standard networks is increasing. Consequently, the gateway function that mediates between these different systems now occupies a very important position.

Currently, the controller area network (CAN) is widely used for control and body systems. However, FlexRay is increasingly being adopted for control systems because it is capable of faster communication. The local interconnect network (LIN) is increasingly being adopted for body systems as a low cost network to connect ECUs with sensors and actuators.

Information systems widely use Media Oriented Systems Transport technology with a 25 Mbps transmission capability (MOST25). The even faster MOST150 or the vehicle-mounted Ethernet based on IEEE802.1 audio video bridging (AVB) is also being considered due to the growing need for high-quality video transmission.

2.8. Vehicle-mounted information systems

The number of vehicle navigation systems shipped in Japan in 2012 was 5,590,000 units, 115% of the previous year (data according to the Japan Electronics and Information Technology Industries Association (JEITA)). There is a continuing shift away from hard disc drives (HDDs) to the use of flash memory as a storage medium, and flash memory now accounts for approximately 65% of the total. However, within the vehicle navigation systems that use flash memory, the number of portable navigation devices (PNDs) continued to decrease, declining by 76% compared to the previous year. One possible cause of this decline is the growing popularity and spread of navigation applications on smart phones. Vehicle navigation systems are continuing to achieve higher levels of performance, including safety functions that utilize camera images and larger sized displays. However, the popularity of display audio systems with more limited functions and optional vehicle navigation functions is also continuing to increase.

The communication speeds of vehicle navigation systems are improving dramatically in conjunction with the spread of long term evolution (LTE) high-speed data communication services and wireless local area networks (LAN). Consequently, there is a continuing shift away from using standalone navigation services to navigation systems that connect to a server or other portable device, such as a smart phone. It is predicted that vehicle navigation services will evolve from telematics services that obtain and use probe information and travel history information to functions that utilize the diversity of smart phone applications and provide the convenience of access to the latest information.

As of December 2012, a total of 36,530,000 on-board Vehicle Information and Communication System (VICS) devices for traffic information have been shipped (data according to the Vehicle Information and Communication System Center). In 2011 there were ITS spots installed in approximately 1,600 locations in Japan, mainly on highways. In 2012 ITS spots continued to be installed on newly completed roads. On-board dedicated short range communication (DSRC) devices that can communicate with these ITS spots have started to gradually spread and grow in popularity. Conventional user interfaces for these on-board DSRC devices are linked to the vehicle navigation system or are voice activated. However, there are now devices on sale that can be connected to smart phones, the same trend as seen for vehicle navigation systems. These functions provide voice and image services and are helping to promote greater adoption of on-board DSRC devices.

2. 9. Audio systems

In 2012, the number of vehicle CD players that were shipped in Japan declined slightly to 3,350,000 units (7.2% less than the previous year). However, China has been the number one vehicle market in the world for four consecutive years and the number of vehicle CD players shipped in China grew to 12,120,000 units (5.5% more than the previous year). In India, shipments rose to 1,420,000 units (10.5% more than the previous year). Therefore, sales are likely to continue expanding in emerging markets in the immediate future. The global demand for vehicle audio systems is predicted to continue to grow slowly in the future (sales data according to JEITA).

As in previous years, the key to further growth and popularity in vehicle audio systems is USB and Bluetooth connectivity functions that allow songs already downloaded onto smart phones and portable music players to be played through the vehicle's audio system. USB connections are advantageous since power can be supplied to the portable devices, but connections using physical cords are somewhat inconvenient for users. In the future, it is likely that the demand for more convenient wireless connectivity will increase and the popularity of non-contact charging technology will also increase.

In North America the popularity of satellite and hybrid digital (HD) radio continues to increase. Many governments in European countries are also promoting the switch to digital radio, so there is an urgent need to develop vehicle audio systems compatible with Digital Audio Broadcasting (DAB) in Europe. It is expected that the number of vehicles equipped with a digital broadcast receiver will only increase in the future.

At the same time there is also greater demand, mainly in North America and Europe, for display audio systems that can connect to smart phones and give access to internet radio, traffic information, video streaming applications, navigation services, and the like. The audio system must have functions that display this information on its touch screen for use. The global demand for such display audio systems is likely to rise and the number of units sold will also probably continue to increase in the future.

In the future, vehicle audio systems will continue to evolve and grow in popularity based on connectivity to smart phones and other portable devices, as well as based on functions that deliver greater convenience to users.

2. 10. Safety devices

In 2012, the number of traffic accident fatalities in Japan was 4,411 people. This number has declined for 12 consecutive years and is now less than 30% of the peak number. However, there are still tragic accidents with numerous fatalities and injuries on highways involving large trucks and buses. Although the number of traffic accidents and injuries has declined for eight consecutive years, it still remains at a high level. Continuous efforts will be necessary in the future to further reduce the number of fatalities, injuries, and incidents of traffic accidents.

Given these circumstances, the Japanese Ministry of Land, Infrastructure, Transport and Tourism 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 20 tons) from 2014 and installation has also been ordered for buses with a gross vehicle weight of over 12 tons from 2014. Automakers are also moving to equip passenger vehicles with collision mitigation brake systems and other preventive safety equipment such as lane departure warnings, blind spot warnings, and the like. Accordingly, collision mitigation brake systems have started to be installed on light vehicles as well. It is predicted that the use of such preventive safety equipment will continue to spread with encouragement from the Japanese government as the perimeter monitoring sensors (millimeter wave radar, laser radar, stereo cameras, monocular cameras, and the like) that are used in this equipment come down in cost.

Starting in the 2012 fiscal year, the Ministry of Land, Infrastructure, Transport and Tourism has formulated a new 5-year Technology Basic Plan. One priority project in this plan focuses on the realization of safe, secure, and efficient transportation. In this project the ministry will begin research into new traffic safety measures, such as promoting the development of technical standards and guidelines for the Advanced Safety Vehicle (ASV), as well as carrying out research and development that utilizes probe data to identify dangerous locations on roads.