Electric Equipment

1 Introduction

Expectations placed on automobiles in areas such as the environment, safety, and comfort are changing rapidly, and greater importance is being placed on automobile electrification and electric equipment.

In terms of environmental concerns, more stringent fuel regulations are spurring greater adoption of electric motors, as exemplified by electric and hybrid vehicles. And, as illustrated by the launch of the world's first sedan fuel cell vehicle (FCV) in 2014, new technologies are also actively being developed. Despite the vigor directed at new technologies, the conventional internal combustion engine (ICE) will remain predominant for the foreseeable future, and ongoing efforts are being made to further increase its efficiency.

In alternators, addressing the power demand of on-board systems calls for increased power output and control of generated power through coordination with the vehicle. Starters are not only expected to become lighter and more compact, but are also required to satisfy strict durability requirements to cope with the increased frequency of starts brought about by start-stop systems. In addition, there is a growing need for spark plugs that ensure high ignitability even under conditions that make combustion difficult, including high exhaust gas recirculation (EGR) and lean burn. At the same time, electric power steering (EPS) systems are no longer limited to compact and mid-size vehicles, and have started making inroads into the heavy-duty vehicle market. In response to the publication of a functional safety standard (ISO 26262) in 2011, systems that build redundancy into sensors, motors and inverters and ensure safety in the event of a failure are being developed.

In the field of information systems, instrument panels are increasingly designed to display information related to the environment, such as fuel economy, or to safety systems, such as collision mitigating brake systems. On-board entertainment systems that provide Internet-based streaming services rather than simply play music are expected to become more common. Moreover, cooperative vehicle control involving several control units is becoming critical, and multiplex communication systems where data is exchanged between multiple interconnected devices such as sensors, actuators, and electronic control units are becoming larger, faster and more diverse.

On a global level, emerging countries are at the forefront of the advance of motorization. In Japan, 2014 marked a record proportion of elderly people among the total number of traffic accident fatalities, one indicator of the rise in the number of accidents involving the elderly. Initiatives to reduce traffic accidents currently being assessed include the mandatory installation of collision damage mitigating brake systems in heavy-duty trucks in Japan, as well as incentives to install such systems on ordinary vehicles. To make automated driving systems a reality, development directed at various on-board sensors, more sophisticated map information, and cooperation with infrastructure are underway.

2 Technological Trends in Automotive Electric Equipment

2. 1. Electric equipment for charging systems

As the adoption of electronic control and electric vehicle parts proceeds, the power demand of on-board systems continues to rise. Addressing that demand calls for improved fuel efficiency based on battery charge control adapted to vehicle running conditions in addition to increasing the power output of the alternator, a core component of the charging system. Start-stop systems seek to improve fuel efficiency, and products that mount an inverter on the alternator, augmenting their power generation function with a motor function and turning the crank pulley via a belt drive to start the engine have been commercialized. Systems that use a lithium-ion battery to recover a greater amount of energy in systems that regenerate energy during deceleration have also been commercialized, and such systems rely on pulse width modulation (PWM) signals and local interconnect network (LIN) communications to achieve fine-grained control of the alternator. The continued rise in power demand and the magnification of wire harness current loss and mass have led European automakers to draw up a 48 V standard.

Efforts to make the alternator itself more efficient include adopting denser coils and multiple poles, as well as setting magnets between rotor poles to reduce leakage flux. In addition, initiatives such as decreasing power consumption in rectifiers through the use of MOS, adopting compact single-chip regulator ICs, and reducing heat loss by enlarging the surface area of the power diode heat dissipation fin are being undertaken to make semiconductor components more efficient.

2. 2. Electric equipment for starting systems

The growing number of auxiliary devices around the engine, along with the higher density of the engine compartment resulting from the expansion of occupant cabin space is creating a need for smaller and lighter starters. Consequently, many vehicles now make use of compact, high-torque gear-reduction starters with a built-in deceleration mechanism. High performance ferrite magnets and higher built-in reduction ratios are also making motors more compact, and weight reduction efforts are advancing.

At the same time, as fuel economy regulations are becoming stricter, sales of passenger vehicles equipped with a start-stop system in Japan are increasing. Moreover, to achieve further improvements in fuel efficiency, a growing number of systems prolong the time the engine is turned off by stopping it before the vehicle comes to a complete stop, and it is expected that engines will become subject to more frequent stops. Restarting the engine more often naturally involves significantly increasing the use of the starter. New starters will therefore be required to withstand more frequent use than existing ones. Reducing starting noise is another issue to address as systems that restart the engine before it stops completely are also becoming more common. Smooth vehicle take off after stopping makes reducing the engine restart time an ongoing imperative.

2. 3. Electric equipment for ignition systems

Ignition systems consist of the ignition coils set in each cylinder, the ignition lamps, and the angle sensors used to detect the rotational angle of the crankshaft or camshaft. Those systems will have to become more sophisticated, smaller and lighter to address the demand for greater fuel efficiency. The demand for higher voltages stemming from the broader adoption of supercharged downsized engines, particularly in Europe, as well as adaptation to direct injection engines and high EGR, is creating a growing need for high-energy ignition coils. Due to their high-efficiency magnetic circuits and superior mounting flexibility, plug top-type ignition coils are gradually replacing the spark plug hole-type, which houses the winding portion of the coil within the spark plug holes.

The need for ignition lamps featuring reliable ignitability even under conditions that make combustion difficult, including high exhaust gas recirculation (EGR) and lean burn, is also growing. Longer reach for threaded fasteners is another area of rising demand as M12 has replaced the conventional M14 as the primary thread diameter. At the same time, ways to improve durability to accommodate the demand for high voltages and the use of narrower discharge electrodes to improve ignitability are being examined.

Digital output sensors, which feature excellent signal detection precision, signal control, and mountability, and can detect the angle directly from the crankshaft or camshaft as well as be attached directly to the engine have become the mainstream angle sensors. With the recent spread of start-stop systems, measures to improve restarting have led, in some cases, to the adoption of sensors with functions to detect the direction of rotation of the crankshaft as well as the position where the piston stopped. The mounting of angle sensors on both the intake and exhaust camshafts is becoming more common as the adoption of variable valve timing mechanisms for both intake and exhaust systems increases.

In the context of the development of even more fuel-efficient next-generation engines, new discharge technologies reaching beyond the bounds of conventional ignition coils and lamps are also being developed, and expectations surrounding the evolution of the ignition system as a key technology in enhancing combustion remain high.

2. 4. HVAC equipment

Innovations are required of HVAC systems in response to new regulations on refrigerants as well as to the major changes being applied to powertrains to address environmental issues.

HVAC systems with cold storage evaporators that store cold air while the engine is running and use it to cool the cabin when the engine is stopped are being commercialized for vehicles equipped with stop-start systems. Since they have no engine, electric vehicles relied on electric heaters as the heat source for the HVAC system, but such vehicles are now being equipped with heat pump systems featuring high heating efficiency to avoid reducing cruising range. Nevertheless, ensuring heating performance at extremely low temperatures remains an issue.

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, leading to the gradual adoption of a new refrigerant called HFO-1234yf. At the same time, HFO-1234yf is also known to produce a toxic gas if ignited in an accident. Therefore, initiatives to switch to the use of CO_2 as a refrigerant due to its lower environmental impact are also underway. However, CO_2 refrigerant must be used under high pressures, which presents difficult engineering issues, leading to concerns that the weight and cost of the HVAC system will greatly increase.

In addition, the discrepancy between the test cycle fuel economy listed in catalogs and actual fuel economy is drawing attention. For hybrid vehicles, which have a high test cycle fuel economy, the impact of the HVAC system on the discrepancy between test cycle and actual fuel economies is significant, making it important to increase the efficiency of the HVAC system.

2. 5. Steering

An expected improvement of 3 to 5% in fuel economy over conventional hydraulic power steering (HPS) has expanded the market for electric power steering (EPS) systems both inside and outside Japan, particularly for compact and mid-size vehicles. In the European and U.S. markets, the strengthening of fuel economy regulations since 2010 has led to replacing the conventional HPS systems in heavy-duty vehicles and SUVs with rack assist EPS systems. In emerging markets, the demand for column assist EPS, especially for inexpensive compact vehicles, is surging and is anticipated to grow even more. Such trends are expected to lead to a long-term contraction of the market for the hydraulic pressure-based electro-hydraulic power steering (EHPS) and HPS systems. In response to the publication of a functional safety standard (ISO 26262) in 2011, EPS systems that build redundancy into sensors, motors and inverters and ensure safety by enabling continued steering assist in the event of a failure are being introduced in the market. Integrated control is also being applied to coordinate EPS control with advanced support systems such as driver or parking assistance systems that use cameras and radars. In turn, this will lead to greater momentum in developing EPS systems adapted to automated driving.

2. 6. Displays and instrument panels

Until now, the main function of the instrument panel was 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 spread of fuel economy-related displays as well as the expected increase in the provision of information related to safety equipment such as collision mitigation brakes.

In the area of standards and regulations, the criteria to evaluate the safety of new vehicles have changed to a methodology that assigns higher scores to vehicles equipped with on-board cameras, and the adoption of laws making rear view support mandatory in North America will increase the number of vehicles equipped with rear view displays. In addition, the adoption of digital rear view mirrors to supplement indirect vision is being debated as part of international standardization activities, and mirror systems using displays are likely to be introduced in the next few years.

Installing screens in instrument panels has recently become common, and such screens are expected to become larger to provide even more information on driver assistance and vehicle conditions. User expectations regarding image quality are rising, and center displays are becoming larger and switching to high definition resolutions. In addition, greater coordination between on-board devices and smartphones is being pursued to enable the safe use of smartphone functions while driving.

Head-up displays (HUDs), which project driver assistance information on the windshield, are drawing attention as a safe means of conveying information since they require little line of sight switching while driving. HUD displays are increasing in size and moving to full color, and they are also expected to spread to standard vehicle classes. As driver assistance functions become more advanced and more aspects of driving become automated, the instrument panel will play an ever more critical role in linking car and driver to convey information on vehicle condition as well as ensure the driver remains alert.

2. 7. Multiplex communication systems

Advances such as automated driving and connected vehicles are significantly increasing the amount of data processed on board, and cooperative control involving multiple control units is becoming more crucial. Consequently, multiplex communication systems where data is exchanged between multiple interconnected devices such as sensors, actuators, and electronic control units are becoming larger, faster and more diverse. It is common for fields such as vehicle control systems, body systems, or information systems to use their own specific standard communication protocol, a situation that makes the gateway unit used to mediate between different systems critical.

The controller area network (CAN) and LIN protocols are widely used in vehicle control and body systems, with FlexRay (note: FlexRay is a registered trademark of Daimler AG), which is capable of communicating at higher speeds, is also starting to be used. Further, the examination of CAN with Flexible Data Rate (CAN FD), a protocol that extends the existing CAN only in the area of data transfer speed, is being stepped up. For information systems, supplementing the Media Oriented System Transport (MOST) (note: MOST is a registered trademark of SMSC) protocol with on-board integration of Ethernet (note: Ethernet is a registered trademark of Xerox Corp), which allows faster transmission of data such as images and maps is under consideration, and proposals for dedicated on-board systems with simplified wiring have been presented. Vehicles have also started to incorporate universal serial bus (USB) and Bluetooth (note: Bluetooth is a registered trademark of Bluetooth SIG, Inc.) wireless technologies to communicate with smartphones.

2. 8. Vehicle-mounted information systems

In 2014, shipments of vehicle navigation systems in Japan rose 0.3% to 5 million units, the first positive growth in two years (source: Japan Electronics and Information Technology Industries Association, JEITA). Flash memory accounted for 86% of all storage media. As automakers are introducing their own in-house protocols to coordinate on-board devices and smartphones, the major players in the smartphone industry are proposing their own standards (CarPlay for Apple, OAA for Google), reflecting the active entry of IT businesses in this market. Open platform architecture is increasingly being adopted as the platform for on-board information devices, and IT businesses are getting involved in activities aimed at building automotive information platforms. In the area of roadside services, the cumulative total shipments of Vehicle Information and Communication System (VICS) devices reached 43 million units in 2014. By contrast, on-board Electronic Toll Collection (ETC) shipments dropped for the second consecutive year, leveling out at 3.28 million units.

With the provision of information shifting to cloud-based services communication and security technologies will become crucial for on-board information devices. Moreover, automated driving initiatives based on coordination with advanced driver assistance systems (ADAS) are being actively pursued.

2. 9. Audio systems

In 2014, shipments of car CD players declined for a fourth consecutive year, falling by 8.2% over the preceding year to 2.72 million units, while DVD player shipments rose 56% to 230,000 units, the first positive grown in four years (source: JEITA).

In Japan, 90 percent of music comes from the sales of primarily CD-based packages, and the remaining 10% is downloaded. By contrast, in the global market, the share of streaming services transmitting music for free or allowing unlimited listening for a set price has expanded to approximately 10%. Since streaming services are often provided via smartphones, coordination with smartphones has become an indispensable function in car audio systems. Internet-based streaming and other services provided through coordination with smartphones are expected to grow in popularity. Accordingly, to provide users with a human machine interface (HMI) that enables audio devices to coordinate with smartphones, the market for audio devices featuring an integrated display (display audio) is expanding. The standardization of display audio connection protocols is reaching beyond music into a new market that offers navigation functions build on smartphone-vehicle coordination. Outside Japan, broadcasting systems are increasing shifting to digital radio. Audio systems are now also used to deliver informational content (e.g., weather and traffic reports), and expectations for products offering new functions are high.

2. 10. Safety devices

In 2014, traffic accidents in Japan killed 4,113 people and injured 711,374. Although the number of traffic accidents and injuries has fallen for 9 consecutive years and the number of traffic accident fatalities has dropped for 14 consecutive years, the drop in fatalities is becoming less pronounced in recent years. Reasons for this include the rising elderly population, seatbelt and airbag use ratio reaching a peak, and the leveling off of traffic accidents due to drunk driving. The proportion of elderly people among traffic accident fatalities grows every year, reaching a record 53.3% in 2014, a situation that calls for urgent attention. On a global level, motorization is moving forward in emerging automobile markets, and the volume of vehicular traffic is steadily expanding. Predictions show that if current trends remain unchanged, traffic accidents will be the fifth overall leading cause of death, killing over 2.4 million people, creating a critical situation that demands response from society as a whole. Given these circumstances, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is proceeding with plans for the mandatory installation of a collision mitigation brake system on heavy-duty vehicles. Such systems became mandatory for large trucks (over 22 tons) and large buses (over 12 tons) in 2014, and will be phased in for mid-size trucks (over 8 tons) in 2018, as well as for small trucks (over 3.5 tons) and light-duty buses (12 tons or less) in 2019. Active safety devices are not limited to heavy-duty vehicles, but are also spreading to ordinary vehicles, and the Japan New Car Assessment Program (JNCAP) has undertaken activities to evaluate active safety devices and give them ratings according to uniform test criteria. In a similar vein, the government established the Comprehensive Strategy on Science, Technology and Innovation in a June 2013 Cabinet decision, and is promoting the Strategic Innovation Promotion Program. Automated (autonomous) driving systems that will drastically reduce accidents and congestion are one of the themes of that program, and the next roadmap has been released.

(1) Achieving national objectives such as reducing the number of traffic accidents.
(2) Realization and popularization of automated driving systems.
(3) Commercialization of next-generation public transportation systems.

The above policies guide research and development directed at the commercialization of automated driving systems. In addition to the further evolution of vehicle sensors such as radars and cameras found in existing commercial driver assistance systems, more sophisticated map data, cooperation with infrastructure, and harmony between drivers and systems are becoming ever more crucial factors in making automated driving systems a reality.