Technical Trends Regarding Electric Components for Electric Power Steering Systems

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Initially, electric power steering (EPS) systems were mainly in demand for their energy conservation feature or when hydraulic power steering systems were hard to mount. Recently, however, EPS is in demand for a wide variety of reasons and types of target model have been expanding. It appears that in the future, demands for functions exclusively existing in EPS will be rising, and EPS systems will be evolving to have greater safety and comfort. Present technology and future trends regarding electrical components, a key to EPS systems, are described below.

Key Words: electric power steering, EPS, trend, electric component

1. Introduction

Koyo became the first in the world to succeed in commercializing an electric power steering (hereafter "EPS") system in 1988 for installation on a subcompact vehicle, a column-assist type (hereafter "C-EPS") having a DC motor-driven power assist unit integrated onto a steering column. Since then, this type of EPS system has been expanding market share in Japan, especially in regard to subcompact vehicles.

In Europe also, needs for installation of power steering systems have come to cover even compact vehicles as a rate of the installation has been more and more increasing. Then, since 1996, EPS system has been mounted mainly on the compact vehicles difficult to equip with hydraulic power steering systems.

Initially EPS system was needed as a power steering system principally for vehicles not only in favor of energy saving but also difficult to equip with hydraulic power steering system, while from now on the system would evolve into the more safe and comfortable one in the face of increasing needs for additional functions inherently available in EPS system.

The following are descriptions about the technological trend and future of EPS system's components, particularly its electric components.

2. Components of EPS Systems

The structure of C-EPS is shown in Fig. 1.

Of the components shown in Fig. 1, the torque sensor, motor and ECU (controller) are described in this text.

3. Technological Trends Regarding Torque Sensors

Koyo is presently using a non-contact torque sensor in order to detect steering torque. Koyo has been proceeding with multiple design changes of the torque sensor for performance improvement and cost saving and is now developing the two torque sensors shown below.

1) Low-cost torque sensor
   Same function as the present torque sensor is provided at lower cost

2) High-performance torque sensor
   Upgraded sensor with steering angle signals additional to torque signals

3. 1 Low-cost Sensor

The low-cost sensor has been designed, based on design of the current mass-production sensor, to lower its cost by adopting new materials and reducing the number of its components.

Comparison between the current and low-cost sensors is shown in Fig. 2.
This example aims at restricting the transmission of vibrations generated from brushes slid on a commutator, through brush holders and a motor flange, to a worm housing on the reducer's side.

As EPS systems have come to cover larger-sized vehicles, their motor that conditions their assist power needs to be more powerful as a natural consequence. The current brushed motor could not provide sufficient output power to high-power type EPS systems any more.

For this reason, development of a brushless motor has become indispensable.

Features of the brushless motor are shown in Table 1.

4. Technological Trend of Motor

The mass production of EPS motor was started with a 25A class, and its output capacity has increased to 65A as EPS-equipped vehicles have become widespread from the subcompact class to the compact class. As the motor has been upsized along with its more powerful output capacity, the restriction of its packaging in the vehicle has run into problems. Against such problem, Koyo has attempted to optimize the motor by not only improving its wire winding technology, but also by adopting high-density wire winding. As a result, the brushed motor has come to be almost available in series according to output capacity, thus optimally selected in combination with reducer for any required assist force, resulting in presentation of an optimal system.

Under these circumstances, EPS systems have come to cover not only subcompact and compact vehicles but also even medium-size vehicles wherein the quietness has been improved so much as to condition strictly the noise level of EPS system. On the contrary, the motor has come to be noisier as it has become more powerful. Therefore, some improvements are required to reduce the motor noise.

An example of the improvements is shown in Fig. 3.

Major differences between the low-cost and current sensors are described as follows.

1. On the current sensor, SUS is used for cores of coil ass’y and for detection rings, while it has been changed into a new material on the low-cost sensor. In addition, this material change allows a sintering process to be eliminated.

2. The current sensor includes three separate components-the detection coil, compensation coil and distance piece—that are integrated into a single resin-molded piece on the low-cost sensor, with the new material.

The structure mentioned above is now under patent application.

3. 2 High-performance Sensor

Recently, customers have been demanding an additional function of EPS system that can detect steering angle and output its signal to different ECUs other than that for the EPS system.

The demand is grounded on the necessity for making the signal available to control different systems such as ABS, ESP, and BCM that have come into wide use in response to customer needs for further vehicle safety and driving comfort.

Currently, a specific steering angle sensor is separately installed in the column to output the signal. Under these circumstances, a trend toward equipping EPS systems with the same function as the separated conventional sensor has been growing as vehicles have been equipped with EPS systems much more. This trend targets mainly the lower cost and better mountability of the sensor.

Accordingly, the development of EPS systems with an integration of torque sensor and steering angle sensor will likely become more important in the future.
Although the brushless motor has many advantages in performance in comparison with the current brushed motor, especially in regard to cost, which has been a barrier against its application to EPS systems.

However, the brushless motor will become a mainstream EPS system's motor if the cost and technological matters are resolved in the future.

Major technological differences between the brushless and brushed motors are shown below:

1) Mechanical switching between the brushes and commutator of brushed motor is replaced by non-contact electronic switching of brushless motor. As a result, the service life of the motor that has been dependent on brush wear is lengthened by the electronic switching, and the absence of brushes and commutator enables the motor to be downsized. In addition, the absence of mechanical contact is advantageous in noise reduction.

2) On the brushless motor, permanent magnets (magnetic field system) are used as the rotor, and wound coils (armature) are a part of the stator, inversely to the brushed motor. As a result, such difference in configuration and specific gravity of the components allows inertia to be lower on the brushless motor than on the brushed motor, so that a good effect can be given to steering feel in EPS system.

5. Technological Trends Regarding Controllers

Development of controllers started with 25A-class, in the same way as motors, and at present, controllers capable of covering of 65A at maximum are under mass production. They are also designed for a series of sizes and shapes according to amperage in the same way as motors.

On the other hand, controllers have been conventionally installed nowhere else but vehicle passenger compartment. However, on some vehicles, they have come to be installed in the engine room, wherein they might be defined specifically to endure the effects of water, heat, etc. Types of controllers currently under mass production or development are classified in Fig. 4. They can be roughly classified into 3 types: for column-type EPS (installed in the passenger compartment), for pinion-type EPS (installed in the engine room), and for EPS with higher power (by brushless motor). Some of the controllers for column-type EPS integrate a torque sensor circuit for mounting on column.

Exposed to severer environmental conditions than those in the passenger compartment, controllers in the engine room need to be protected more carefully than conventionally done in EPS systems. Within the framework of such protection, a temperature sensor is added to the controller or torque sensor in the EPS system for direct measurement of its own temperature, of which the signal allows such protection to be optimally controlled.

An example is shown in Fig. 5, where an exothermic effect can be suppressed by a shorter time of power application to the motor at high temperature for such protection

![Fig. 4](image-url) Classification of EPS controllers

![Fig. 5](image-url) Example of derating control as a function of ambient temperature
5. 1 Storage and Selection of Various Characteristic Maps

Since no EPS-equipped vehicle had so many variants in grade until recently, one assist characteristic was good enough to cover target vehicles. However, as the rate of EPS-equipped vehicle has risen, variants in the same vehicle have also increased, so that it has become more and more difficult to offer an assist characteristic that can be adjusted for all the variants. Under these circumstances, there have been more and more cases wherein the suitable assist characteristic among several ones stored in the ECU is selected so as to match with the variant of vehicle defined according to grades and options by the vehicle manufacturer at the final assembly process. This selectability of characteristics enables the initial one to be changed to the other alternatives at the request of vehicle manufacturers and/or in accordance with reactions in market. It is inevitable that such demands for storage of the various assist characteristics will grow more and more in the future to meet customers' diverse requirements.

5. 2 Reinforced Communication Function

Conventionally, the controller has admitted the input of various signals (mainly for vehicle speed signal, engine rotation speed) directly from the respective sensors or indirectly via the other controllers. Recently, Controller Area Network (CAN) has come into wide use among vehicle manufacturers since it enables a significant reduction in the number of wires used for controllers by sharing any information required for on-vehicle different controllers in one common line.

Examples of block diagram with/without CAN bus are shown in Fig. 6-a and Fig. 6-b.

Examples of input to controllers are also shown in Fig. 7-a and Fig. 7-b. Compared with Fig. 7-a that includes no CAN circuit, Fig. 7-b shows an input circuit simplified with CAN line. Some torque sensor circuits with built-in ECUs are highly simplified, without the torque sensor signal input line shown in Fig. 7-b, but with input signals for nothing but IG Key, power supply and CAN and output signal for no more than the motor line.

6. Approach to Additional Functions of EPS

EPS systems, which have been recognized as merely electric-powered alternatives of hydraulic power steering systems, are now being transformed into a part of vehicle integrated control systems. The following are some examples of those systems presently under consideration, which take into account the ones already mass-produced by competitors. For feasibility of those systems, it is indispensable to make a full deliberation on safety. However, those systems, that are represented by new functions of EPS systems and a commonality of the EPS sensor data with other systems, including peripheral technologies of vehicle integration control, will be more and more widespread and diversified hereafter. Therefore, the development of high-performance torque sensors and the sophistication of communication functions are of significant importance as described above.
<Future vehicle integrated control systems>

1. Automatic parking function
   Enabling automatic parking by use of such vehicle information as steering angle and position, and vehicle speed

2. Lane-maintaining assistance system
   Supporting straight-ahead driving of a vehicle by monitoring lanes and vehicle speed

**Figure 8** shows future trends of EPS systems described herein.

![Future trend of EPS system](image)

**Fig. 8** Future trend of EPS system

### 7. Conclusion

Electric components have conventionally been critical key elements for EPS systems. Because demands for the system to have additional functions other than the original steering function as well as to be integrated with other systems are growing more and more, the electronic components, especially the controller, are becoming more and more important. It is essential not only to enhance furthermore the control technology proper to the system for better steering feel, but also to develop and offer additional functions of the system alone or together with other systems for improvement of vehicle safety and comfort.

### References


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