Product Introduction

Development of Electric Power Steering Responsive to Next-Generation Needs

MATSUMURA Ryoichi

1 Introduction

The demand for electric power steering (hereinafter "EPS") has been on the increase in recent years. The EPS market annually sells 60 million units. Vehicles equipped with EPS are on pace to account for nearly 60 percent of total vehicle production. The steering feel and assistive output of EPS has always been said to be inferior to that of hydraulic power steering (hereinafter "HPS"), which was the dominant product in the power steering market. Behind the increasing demand for EPS there have been great efforts by EPS manufacturers to make up for the gap.

The recent tremendous advance in electronic control technology has dramatically sophisticated automobiles. EPS uses an electronic control system to drive the motor and can be added with extra functions that could not be achieved with HPS. With this feature, EPS can more easily be combined with other vehicle devices, offering higher contribution to integration control. For vehicles with more and more additional functions, EPS is an indispensable device.

Demand for EPS is expected to grow continuously. EPS development is entering a turbulent stage. We, as engineers, are responsible for constantly launching even better products and should never be satisfied with the current situation. This article introduces an EPS system we have developed in order to meet the demand for next-generation EPS (Photo 1).

2 Desired Next-generation EPS

To ensure that drivers can enjoy safe, environmentally-friendly driving with low fuel consumption, EPS is required to have the following features:

① Improved steering feel
② Smaller, lighter unit
③ Improved safety

2.1 Improved steering feel

Drivers can enjoy driving when they can control the vehicle at will. The feeling can be expressed by sensibilities such as comfortability or satisfaction.

An EPS system that transfers the steering input to the tires as the driver likes is ideal for the vehicle. Such an EPS can achieve the ultimate steering feel.

2.2 Smaller unit

The EPS system needs to be reduced in size and weight to be installed in a smaller space due to the increasing number of vehicle devices for additional functions, and to meet customer demand for improved fuel consumption.

2.3 Improved safety

Recently, automotive electrical and/or electronic systems are required to conform to the ISO 26262 standard. With an eye toward autonomous driving, the EPS system needs to achieve an even higher safety level.

Photo 1 Newly developed EPS

3 Improved Steering Feel

The force transfer route for the rack bar (Fig. 1) to start moving was analyzed for improvement. With a focus on the elements listed below, the rack bar has been improved to be able to smoothly start moving:

① Rack & pinion section
  A) Pressure pad sheet
  B) Pressure pad elastic ring
② Input shaft section
③ Reduction gear
④ EPS tuning with various controls

3.1 Rack & pinion section

A) Pressure pad sheet

Input of steering force from the steering wheel to the rack & pinion (hereinafter "R&P") engagement section (Fig. 1) is converted into a force in the lateral direction of the vehicle, causing the rack bar to slide. A key point of the improvement is how the rack bar can be moved smoothly.

The R&P engagement section includes a part called "pressure pad" to maintain the engagement. The pressure pad is in contact with the rack bar via a resin sheet on which the rack bar is sliding. To ensure smooth movement of the rack bar, a low μ sheet material has been searched for lower sliding resistance. Finally a Teflon sheet material has been selected. In fact, another Teflon sheet that was used in an HPS system was trialed in an EPS system, but replaced with a nylon sheet with high wear resistance because the Teflon sheet had low durability due to fretting. Now, the new Teflon sheet can offer better durability and sliding performance by changing the contact area with the rack bar and using another additive, mostly achieving the target steering feel.

B) Pressure pad elastic rings

The pressure pad bears the spring load and plays a role as an engagement support to press the rack bar against toward the pinion shaft (Fig. 2). This will reliably follow any wear between the gears, constituting a steering structure free from rattle. To ensure the following of the rack bar by the pressure pad, a clearance must be provided between the pressure pad and the housing (Fig. 3). In this configuration, when the pressure pad moves in the radial direction even slightly, the contact between the sheet and rack bar would inevitably change. Then, elastic rings are installed on the perimeter of the pressure pad to provide self-aligning in the radial direction. This achieves the stable steering feel.

The elastic rings also have a role of damping the sound caused by the pressure pad when making contact with the housing. The elastic rings can offer the noise prevention effect.

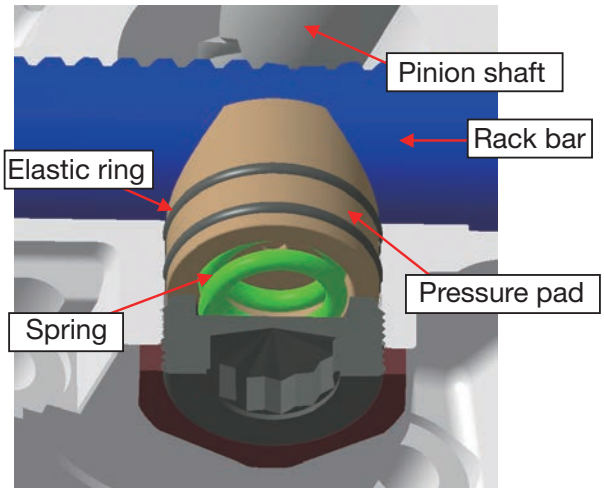

Fig. 2 Engagement support

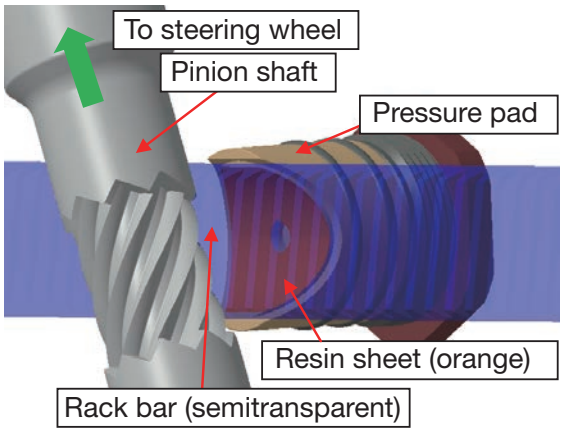

Fig. 1 R&P engagement section

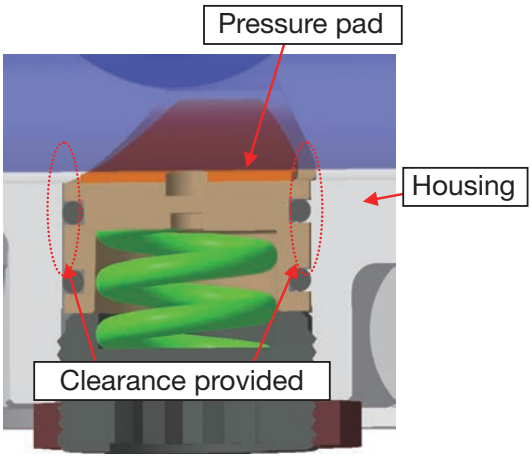

Fig. 3 Clearance between pressure pad and housing

3.2 Input shaft section

The EPS system includes a component called the input shaft consisting of a stub shaft, magnet, torsion bar, magnetic circuit, bushing and pinion shaft (Fig. 4). The input shaft takes the steering force from the steering wheel and reads out the torsional angle of the torsion bar with a torque sensor.

The steering force is transferred to the stub shaft serration-engaged with the column shaft as a turning force. The stub shaft will create a rotary phase difference from the pinion shaft by the amount according to the load via the torsion bar. To ensure reliable transfer of the turning force, the stub shaft bearing, which is called a bushing, has been improved to achieve higher transfer efficiency.

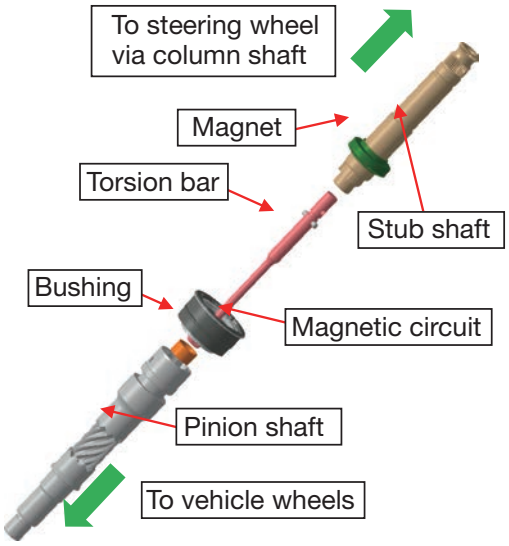

Fig. 4 Developed view of input shaft

3.3 Reduction gear section

The reduction gear section, which consists of a worm shaft and plastic wheel, uses a non-backlash mechanism (Fig. 5) on the end of the worm shaft to provide a pushing force toward the plastic wheel with a coil spring. The pushing force is intended to maintain a uniform engagement backlash, even if there is a dimensional change between the gear shafts due to wear or expansion of the plastic wheel. In this non-backlash section, a reaction force will be generated (Fig. 6). The magnitude and orientation of the reaction force depend on the steering direction (right or left). Through an analysis on the direction and magnitude, the structure of the non-backlash mechanism has been improved to generate the pushing force in the direction that is the resultant of the two vectors of engagement reaction forces for steering right and left. This improvement has eliminated the right-to-left difference.

The right-to-left difference means that there is a difference in steering force between steering right and steering left. This is one of the factors of an uncomfortable steering feel.

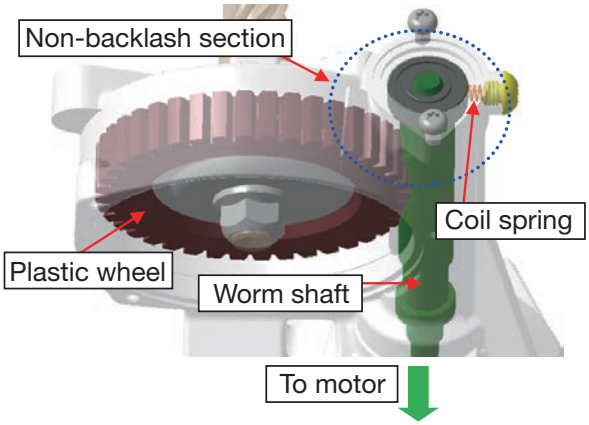

Fig. 5 Non-backlash mechanism

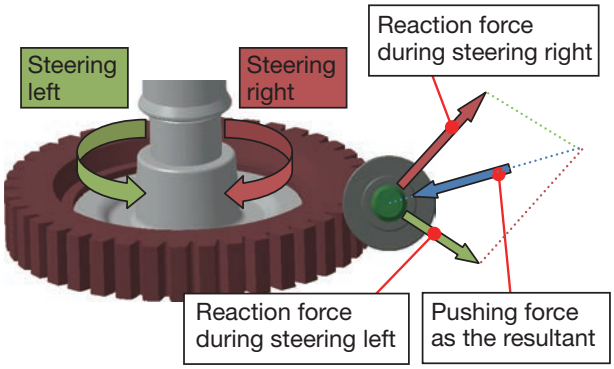

Fig. 6 Reaction forces generated in the non-backlash section

3.4 EPS tuning with various controls

EPS can achieve a variety of steering characteristics and steering feel by using electronic control. Examples of controls contributable to higher performance are listed below:

① Assist control - Determines the steering characteristics
② Phase compensation control - Prevents vibration during steering
③ Damping control - Suppresses minor vibration
④ Inertia compensation control - Improves steering responsiveness
⑤ Wheel return control - Improves steering wheel return characteristics

Parameters for the controls above have been adjusted to achieve an optimal steering feel suited to the vehicle.

4 Smaller, lighter unit

Recent EPS development efforts for smaller, lighter units have a trend of integrating the ECU into the motor. This is called a power pack. ECU has been substantially reduced in size with the advance in electronics technology, resulting in the emergence of the power pack. This has eventually downsized EPS and considerably improved

its vehicle mountability.

There are two types of power pack in terms of structure: rear mount type in which ECU is installed behind the motor shaft (Photo 2) and front mount type in which ECU is installed in front of the motor shaft (Photo 3), when viewed from the interface with EPS. These two types have their connector sections in different positions depending on ECU location. The former can locate the connector section coaxially to have a smart profile in the longitudinal direction although the shaft is quite long. The latter has the connector section protruding in the radial direction, resulting in a larger dimension in the radial direction and a shorter shaft length.

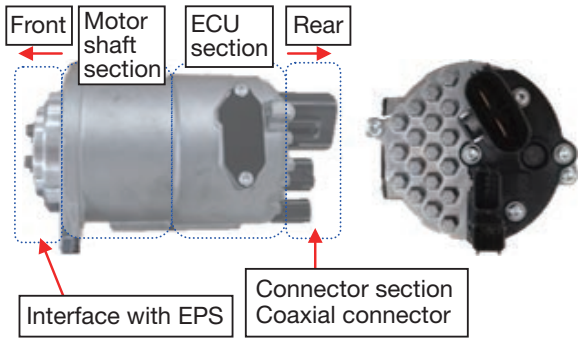

Photo 2 Rear mount power pack

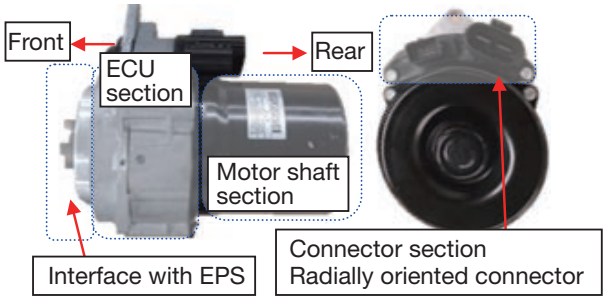

Photo 3 Front mount power pack

Which type is superior in vehicle mountability cannot be simply determined because it depends on the vehicle layout requirements. Anyway, the newly developed rear mount type provides a wider choice of options for various vehicle layouts.

5 Improved Safety

To prove compliance with the ISO 26262 standard on safety of automotive electrical and/or electronic systems, it is important to define the internal development process based on the standard and carry out product development according to the process. The new product has been verified to meet customer safety requirements through functional safety assessment. In the assessment, a check list containing about 650 check items according to ISO 26262 was used. The design and verification documents prepared in the development process were used to explain that the product passes all the check items in the check list. Thus, all those concerned including the customer and business partners have confirmed the compliance with the standard and the satisfaction of the safety requirements.

6 In Closing

Vehicles equipped with the new EPS have been highly valued by journalists who tried the vehicles. I have also frequently seen end user comments on the vehicles that they were impressed by the driving performance. Each of these has convinced me that the development has raised the level of the KYB EPS to a new height that is closer to the desired next-generation EPS. I would like to, on this occasion, thank all the people who extended cooperation in developing the product.

Author

MATSUMURA Ryoichi
Joined the company in 2012.
Corporate Planning Dept., Corporate Planning Div.
Taken present post after working in Steering Engineering Dept., Steering Headquarters.
Was engaged in design and development of electric power steering during working in Steering Engineering Dept.