Future Views on EPS System Technological Development

H. MIYAZAKI

This paper investigates the technologies demanded of future electric power steering (EPS) system with a focus on the three indices of "Environment & Efficiency", "Safety & Reassurance" and "Comfort & Convenience". To contribute to the first index of "Environment & Efficiency", the wider application of EPS system highly effective in reducing fuel consumption and the development of smaller, lighter EPS system with higher efficiency are necessary. Furthermore, development of a highly reliable system, which rarely malfunctions, and technology allowing the EPS system itself to provide "active safety" by supporting safe steering are necessary to contribute to the second index of "Safety & Reassurance". Finally, for the third index of "Comfort & Convenience", control and elemental technology enhancing the steering experience and an advanced steering function reducing the burden on the driver are required.

***Key Words**: electric power steering, environment, safety, comfort*

1. Introduction

Over 20 years have passed since 1988, the year JTEKT began mass production of the first electric power steering (EPS) system to ever be developed. At the time there was only function to assist steering, and the rack force didn't even surmount to 3 kN. Since then, due to increases in vehicle weight and a demand for more sophisticated and diversified performance, additional functions have been added to the vehicle in which EPS system is applied, and a higher rack force is achieved at approximately 14 kN.

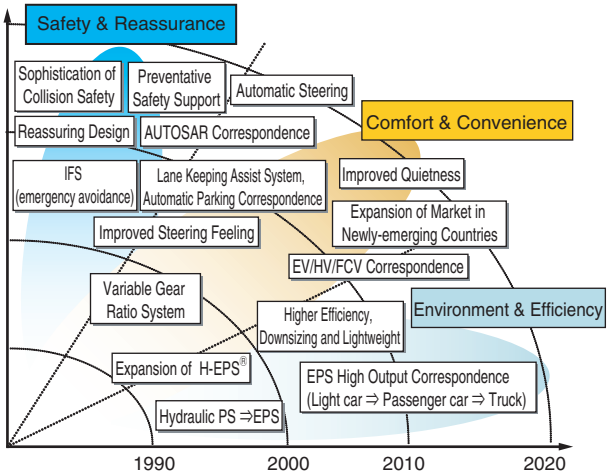

Fig. 1 Steering technology development roadmap

An ever-increasing number of automotive manufacturers are applying EPS system due to the contribution they make to better fuel consumption. This paper discusses the three indices demanded of the EPS system, "Environment & Efficiency", "Safety & Reassurance" and "Comfort & Convenience" (**Fig. 1**).

2. "Environment & Efficiency"

2. 1 Improved Fuel Consumption

Recent years have seen an increase in demand for improved fuel consumption, as vehicle is required to be environmentally designed and discharge less CO_2. To improve fuel consumption, it is necessary to improve engine/drive system efficiency and lighten the vehicle.

The conventional hydraulic power steering (hydraulic PS) uses the driving force of the engine to constantly power the hydraulic pump in order to generate hydraulic power. This creates excess burden on the engine and is one of the reasons for high fuel consumption. The EPS system operates the motor only during steering, therefore reducing the load on the engine, and improving fuel consumption by approximately 2.5%.

Furthermore, in electric vehicle (EV) and hybrid vehicle (HV) with low fuel consumption, hydraulic pump which is operated by engine driving force cannot be used. This has increased the demand for an efficient steering system such as EPS.

The EPS system contributes to lightening vehicle weight, and as such there is a growing need to lighten the EPS system itself. Various lightweight technology

focusing on material and design need to be explored.

Some of the activities required to lighten material used in EPS system is increasing the strength of resin material and widening its scope of application, widening the scope of application for lightweight alloy material such as aluminum and making thinner casting. The design of the EPS system and the use of analytical technology to optimize shape are necessary. One example of this is the reduced number of components made possible through the unification of the motor and ECU.

2. 2 High Output

As stated above, fuel consumption has improved thanks to applying EPS system as an effective steering system, however EPS system does not match the output range of traditional hydraulic PS system, currently (**Fig. 2**).

Efforts are being made to raise output on the Column type EPS (C-EPS®) which is the most commonly produced, and it can now be applied in vehicle with up to 3 Liters engines. However, there are issues concerning achieving even higher output as C-EPS® and Pinion type EPS (P-EPS®) use gear reducers with worm wheels made from resin, therefore limiting output possibilities due to material strength limitations.

This is why, in regards to P-EPS®, the DP-EPS® which features a pinion for power assist and a pinion for manual input to support high output, is being commercialized.

Furthermore, the Rack type EPS (R-EPS®) which uses a ball screw structure for the rack axle, and the H-EPS® which uses a motor driven hydraulic pump, are available as EPS system which supports even higher output range.

In the case of passenger vehicle, it is feasible to lighten the vehicle and reduce PS output, however, luxury and commercial vehicles require high output PS all the more, thus a high performance, lowcost EPS which supports a high output range is required.

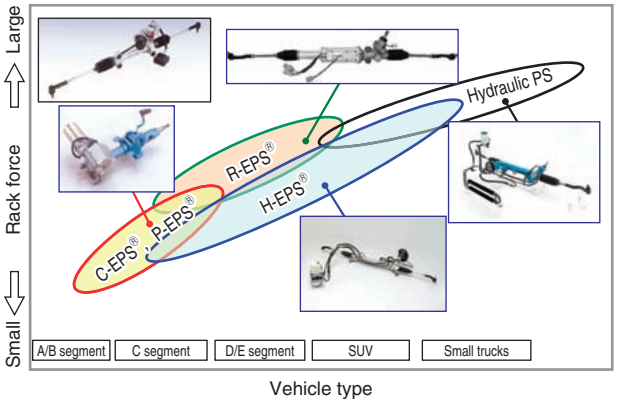

Fig. 2 Power steering system output range

2. 3 Higher Efficiency

To coincide with the wider application of EPS system, there has been an increase in the number of electronic devices featured on vehicle. This increase in electronic devices creates the necessity for power management of the vehicle as a whole. The motor used for EPS is categorized as a large vehicle part, and there is a demand to make it more power saving.

The below 5 items are being prioritized in developments to improve efficiency (**Fig. 3**).

① Reduction of cable resistance loss
② Reduction of DC/DC converter loss
③ Improvement of ECU efficiency
④ Improvement of motor efficiency
⑤ Improvement of mechanical efficiency

As a means to reduce cable resistance loss, drive voltage is being increased through a booster circuit (DC/DC converter) and intermediate cable are being abolished through unification of the motor and ECU. As a means to improve motor efficiency, in parallel to effort to support higher voltage, a high efficiency motor with improved coil occupancy ratio is being developed.

Most current EPS systems use 12 V power source, and efforts to increase drive power voltage also use 12 V as the basis. However, as we predict the increase of vehicle with high voltage main power source (i.e. HV, EV and Fuel-cell vehicles), EPS system should also feature a system, which effectively utilizes high voltage power as the main power source.

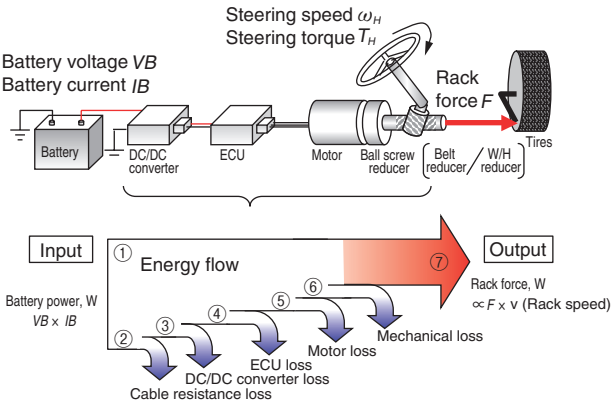

Fig. 3 Power steering energy flow diagram

3. "Safety & Reassurance"

3. 1 Preventative Safety

By combining the R-EPS® and an electronically controlled variable gear mechanism (E-VGR®), a total control system (IFS®) which controls steering angle has been created, adjusting the tire pivot angle in response to the vehicle's driving conditions and offering the driver a safer system (**Fig. 4**).

In other words, the IFS® allows the vehicle to maintain a straight line by preventing the steering wheel from being seized when the friction coefficient of the left/right tire differs to that of the road surface, or disturbance such as sudden crosswinds, etc. There is a demand to offer steering system coordinated with on-board sensor system and ITS (intelligent transport system) in the future.

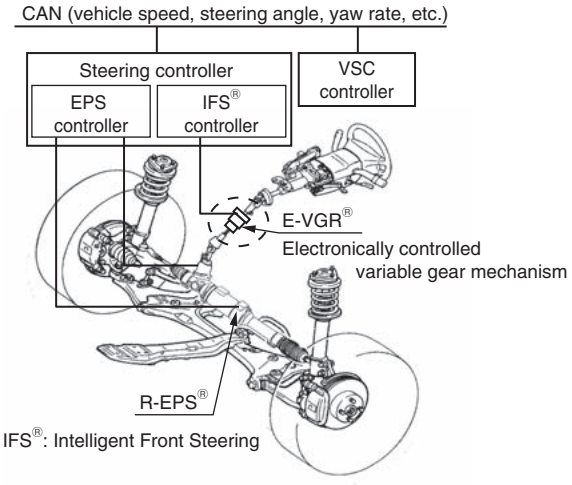

Fig. 4 E-VGR® system configuration

3. 2 Ongoing Steering Power Assist

In conventional EPS, if a system error occurred, the error would be displayed and the system would stop. In case the EPS stops, steering power assist also shuts down, and the driver is subjected to a higher load. Naturally, it is important that errors do not occur in the first place, however there is a demand for the system which offers ongoing steering power assist in the undesired event that an error does occur.

Technologies such as a function which gradually reduces assist if the torque sensor malfunctions, and fixed vehicle speed control if the vehicle speed signal fail are already commercialized, and these are some of the EPS control technologies required to prevent steering power assist from shutting down. Control technology such as ongoing-assist control at motor malfunction and redundant circuit configuration is necessary to improve the safety of vehicle.

3. 3 Corresponding for Safety Standard

Various quality standards are in place to assure the safe performance of system products. These standards also apply to steering system, hence compliance is essential to having a product accepted by vehicle manufacturers. Standards applying to EPS are, ① ISO 26262, ② Automotive SPICE (ISO 15504) and ③AUTOSAR. These relate to safety quality, process quality and product quality, respectively (**Fig. 5**).

In the past, vehicle manufactures implemented their own individual safety measure, however it is becoming necessary to comply with a common standard currently. Amidst this situation, in order to offer a product which has unique features, it is necessary to secure safety performance on a higher dimension after complying with all the various standards.

Fig. 5 Safety standard positioning

4. "Comfort & Convenience"

4. 1 Improved Steering Feeling

In line with the growth of the EPS market, various elemental and control technology are being developed to improve steering feeling. The below is necessary to control improved steering feeling developed to date.

① Inertia compensation control: Removes inertia sensations such as the motor, etc.
② Damping control: Ensures steering contraction
③ Phase compensation control: Ensures control safety
④ Steering wheel return control: Ensures the steering wheel returns to position

The above control technologies have improved the steering feeling of EPS system remarkably. Further development and refinement of control technologies are required to contribute to improving steering feeling even further.

4. 2 High Functionality

In order to alleviate the burden on the driver and support safe driving, the steering system should not only serve the purpose of assisting steering, but should also improve comfort by automatically controlling the steering wheel operation angle itself.

For example, the addition of the E-VGR® actuator could reduce steering wheel angle for situations in which

a large steering wheel angle is required, such as low-speed turns and parking (**Fig. 6**).

Recently, steering system featuring parking assist function and a lane keeping assist system, etc., are being mass-produced.

Development must continue to make sophisticated steering assist system which is even more compact, lightweight and easy to use.

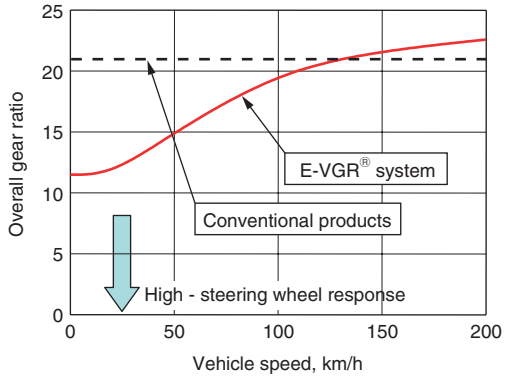

Fig. 6 E-VGR® stroke ratio chart

5. Conclusion

Currently, in line with the increased use of electronics on vehicles, the automotive component industry is changing drastically. Future development of products, including steering system, must pay more consideration to social trends. JTEKT believes this to be an important point for future business success.

We must not only realize steering performance matching the vehicle (body, suspension, tires, brake/drive units), we must also improve the human machine interface to perfect the type of assistance required to meet driver needs, and the way that information is fed back to the driver. The ultimate objectives of our steering system are to make driving more fun, more comfortable and more engaging for drivers the world over.

H. MIYAZAKI*

* *Managing Officer*

OUTLOOKS