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TECHNICAL TRENDS IN STEERING SYSTEMS

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ABSTRACT

Automotive steering systems have gone through the transitions from non-assisted type to hydraulic-assist type, and then, to electric-assist type for its assist. Still, some issues are remaining to adopt the electric-assist type steering to heavier duty vehicles. Therefore, we are depending more on the technology of electrically controlled hydraulic power steering.

This paper covers the technical trends in regard to power steering (PS) energy saving, especially focuses on electronic control of hydraulic PS.

KEY WORDS
Electric Steering, Hydraulic Steering, Energy Saving

INTRODUCTION

Technologies in steering systems have been advancing since hydraulic PS (power steering) for automobiles started to be adopted in the 1950s. Steering systems that support a function of turning are recently facing rapid progress of electronic control in order to meet market needs such as improvements of energy efficiency and safety as well as comfort.

After 1980, an electronically controlled hydraulic PS, hydraulic PS with motor-driven pump, and electric PS have been developed and manufactured. Steering technologies have improved remarkably when compared with conventional hydraulic PS technologies[1]-[3].

The development of electric PS will continuously make progress. However, there still remain various issues such as adoption to heavier duty vehicles and global mass-production. With a background like that, saving energy of hydraulic PS is one of the main issues from an environmental viewpoint.

INFLUENCE ON STEERING ENERGY CONSUMPTION

Current hydraulic PS with constant flow accounts for 3% in the energy consumption of a car. Figure 1 shows the breakdown of the energy loss. The largest energy loss is the over flow loss of pump (1.4%), the second is loss by system weight and efficiency loss from belt & pulley (0.5% each), and the third is the over flow loss by the flow control valve (0.3%).

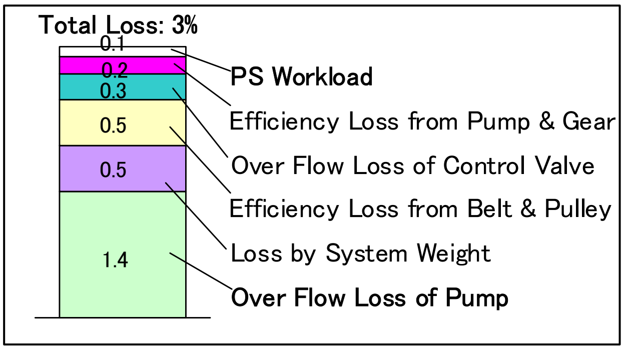

Figure 1 Steering System Energy Consumption

In this system, wasteful energy is consumed when driving straight or driving at high speed that do not require steering operations because the engine-driven hydraulic pump is constantly operating.

As a countermeasure for energy saving, we can provide the following steering systems.

1) Hydraulic type PS with low-flow high-pressure pump
2) Hydraulic-electric type power steering (H-EPS)
3) Electric power steering (EPS)

Figure 2 shows the ratio of energy consumption of these steering systems.

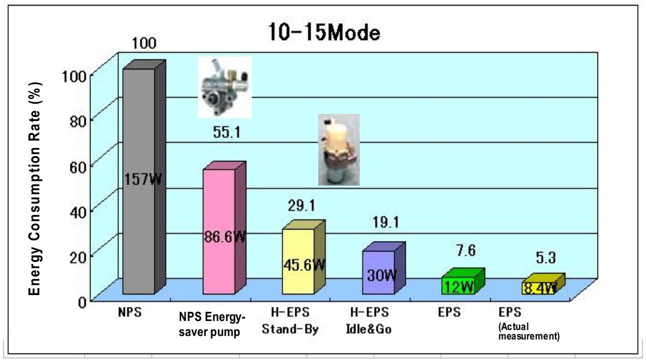

Figure 2 Energy Consumption Comparisons by Power Steering System

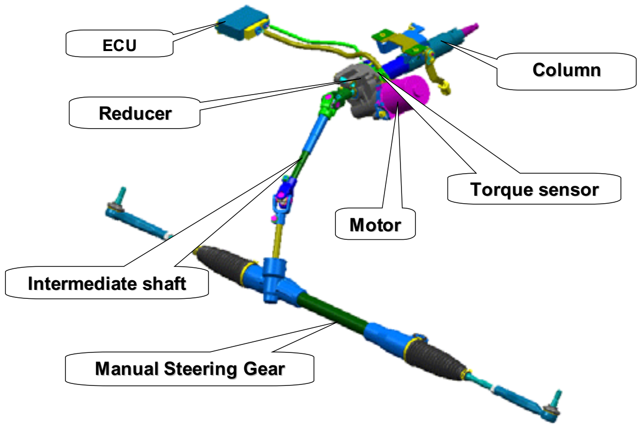

Figure 5 Column Type Electric PS

DEVELOPMENT TRENDS AND ISSUES OF ELECTRIC PS

Since electric power steering (EPS) was first adopted to mini-sized vehicles in 1988, the output power of EPS has been improved. And now it covers from passenger cars to SUV. The number of vehicles with EPS will increase year after year. The EPS is expected to take 40% of the steering market in 2010. (See Figure 3 and 4.)

There are three types of EPS depending on where the motor assist power is supplied (column-assist type, pinion-assist type and rack-assist type). Figure 5 shows a widely used column-type EPS[4].

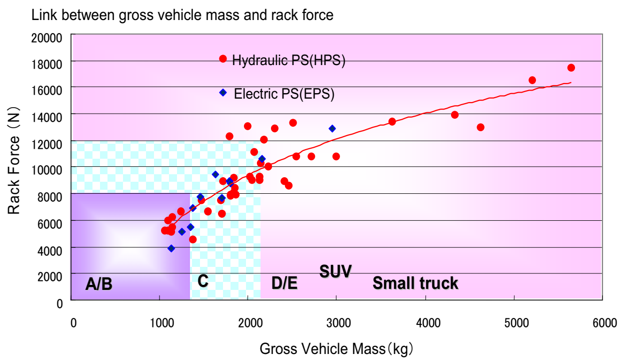

Figure 3 Steering System and Vehicle Segment

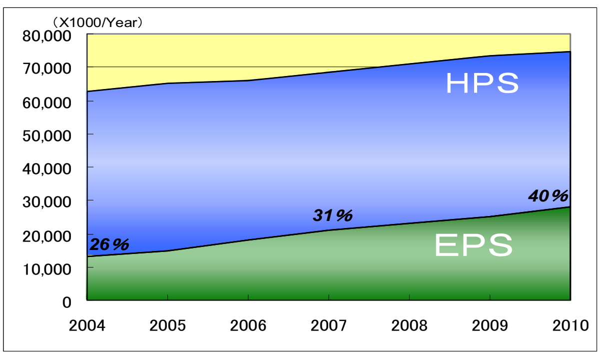

Figure 4 Steering Type Transition

The steering market will accelerate the shift to EPS for improvement of environment and safety. However, we still depend more on hydraulic PS.

The EPS has issues such as packaging, high power, steering feeling, cost, global supply and so on. When high power specifications are required, not all EPS can be installed. It depends on the motor size. The maximum output of EPS is limited by the mechanical strength of the structure. Therefore, it cannot cover all current hydraulic PS range. Regarding steering feeling, drivers have been familiar with the steering feeling of hydraulic PS for a few decades since it was released. Smooth and comfortable steering feeling was realized through fuzzy media, called hydraulic pressure, between a steering wheel and tires. Although the steering feeling of EPS has been improved and getting close to that of hydraulic PS thanks to advancements in electronic controlled technologies, we can say that it is not easy to receive benefit from hydraulic damping effect.

ENERGY SAVING TECHNOLOGY OF HYDRAILIC PS SYSTM

As mentioned above, we are depending more on hydraulic PS. Our energy-saving technologies with some examples are introduced.

1) Hydraulic type PS with low-flow high-pressure pump

As shown in Figure 6, the PS is in unloaded condition (non-steer) for most of the driving time (80 to 90%). Therefore, it is effective to reduce the energy loss. The equation below (1) is a pump consumption torque formula, based on the experiment. The consumption torque of PS pump can reduce its internal pump pressure by reducing the flow in non-steering conditions.

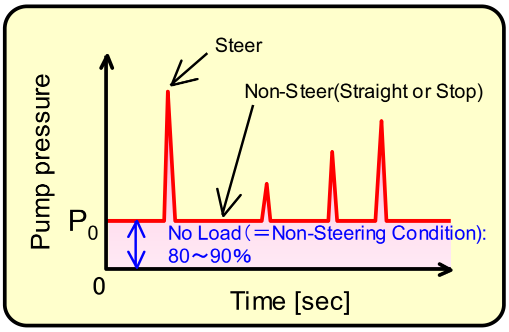

Figure 6　Steering Condition and Pump Pressure

$$T=\underbrace{\frac{Vth}{2\pi}\times(1+Cf)\times P_{IN}}_{\text{Pressure term}}+\underbrace{Cd\times\mu\times Vth\times N}_{\text{Speed/Temperature Term}}+\underbrace{Tc}_{\text{Fixed term}} \quad (1)$$

Vth	:Pump Flow Rate
P_{IN}	:Pump Internal Pressure
N	:Pump Rotational Speed
μ	:Oil Viscosity
Cf、Cd	:Friction/Wear Factor
Tc	:Friction Torque

The external outline of a Variable Flow Control pump is shown in Figure 7. It has a structure to receive signals of vehicle speed and steering angle into the ECU, and go through the compact electromagnetic valve to provide appropriate amount of flow into the pump.

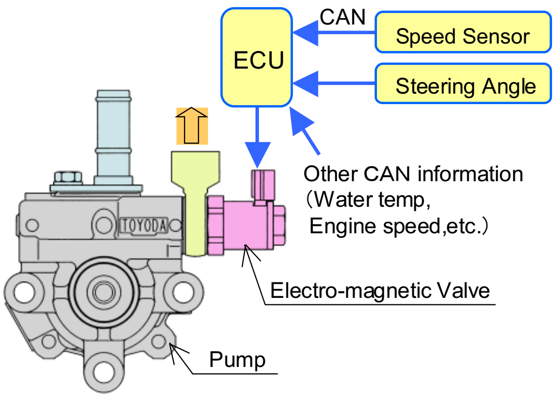

Figure 7　VFC Pump Outline

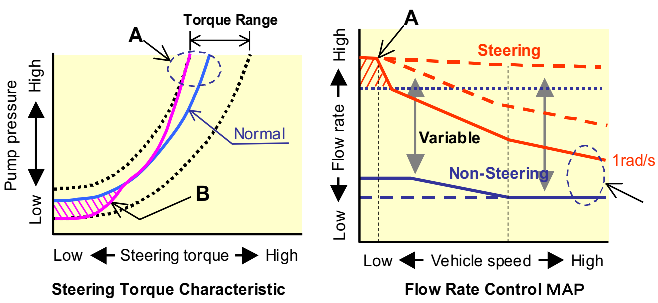

Figure 8 VFC Pump Control Methods

Figure 8 shows a relation between vehicle speed and PS pump flow. It provides comfortable and safe steering operations by reducing the flow in non-steering conditions, and by increasing the flow when driving at high speed or when turning the steering wheel fast.

2) Hydraulic-electric type power steering (H-EPS)

H-EPS is an energy-saving PS, which does not have a pump driven by engine but has an electric pump. The system structure is shown in Figure 9. A pressure balanced gear pump (see Figure 10) has an advantage over a commonly used vane pump in efficiency[5]. It has a feature to rotate the motor appropriately based on the signals of vehicle speed and steering angle. Figure 11 shows the hydraulic control diagram.

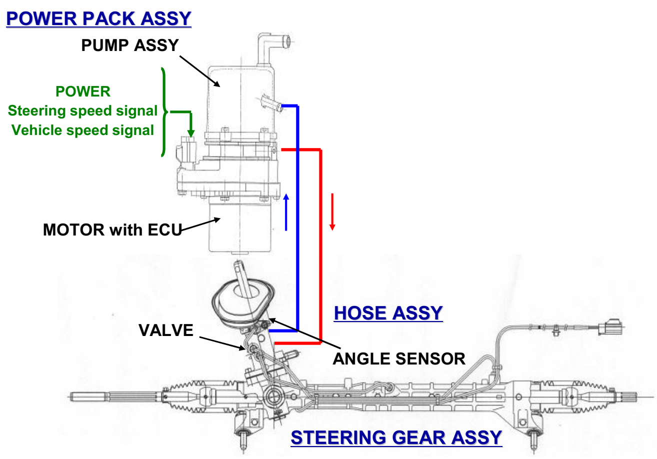

Figure 9 Hydraulic-Electric PS Outlines

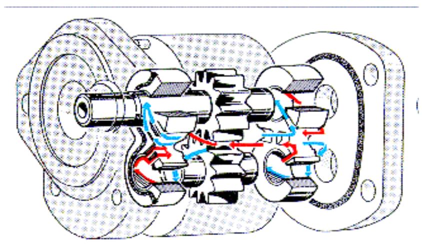

Figure 10 Gear Pump for H-EPS

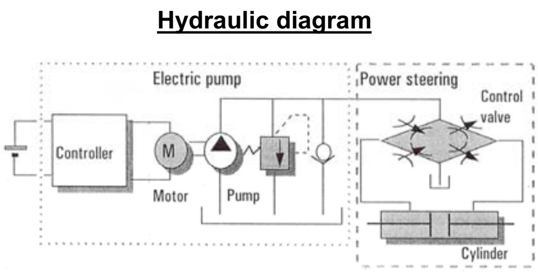

Figure 11 Hydraulic Diagrams of H-EPS

Figure 12 shows a relation between steering velocity and motor rotational speed. It provides comfortable and safe steering operations by reducing the motor rotation in non-steering conditions, and by increasing the rotation when driving at high speed or when turning the steering wheel fast.

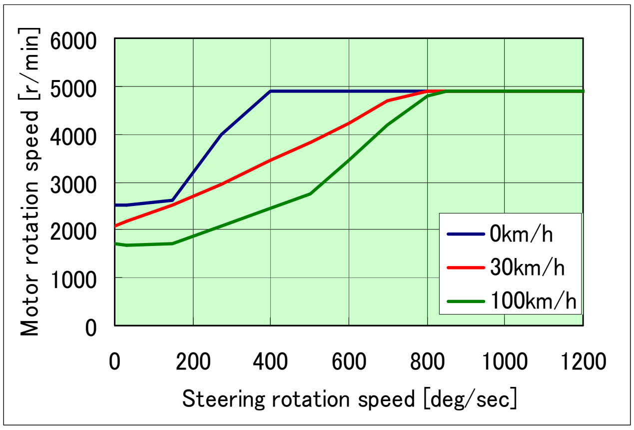

Figure 12 Control Map of H-EPS

The following is a control approach; stand-by type and stop-and-go type[6].

<Stand-by type control>

The simplified low cost controller, without using an external sensor, controls the electric pump efficiently to prevent loss of extra energy. As shown in Figure 12, it puts the motor into low rotation when driving straight or making a stop and into high-speed rotation when power assist is needed.

<Stop-and-go type control>

By controlling the motor with a torque sensor or a steering angle sensor, it stops the rotation of motor while driving straight or making a stop to save energy.

SUMMARY

The steering systems are shifting from hydraulic type to electric type. However, hydraulic PS is a system expected to maintain its market share over 50% even after 2010. Considering the prospects of the market, hydraulic PS combined with electric control technologies that contribute to energy saving is an important technology to support the motorized society. It is expected to bring out the best of the hydraulic PS more and develop the technologies to make further contribution to the world.

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