講演番号	029

文献番号	20225029

Study of Enhanced Responsiveness of Electric Power Steering System Including Digital Delay

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KEY WORDS: **Vehicle dynamics, Steering system,** Steering feel, EPS control (B1)

As EPS has become more widespread, the performance required of it has changed. The increased reliability of EPS required by advanced driving assistance systems is one instance of this. With reliability of communication in mind, torque sensors are also being progressively replaced with digital models, which have better noise tolerance.

Under the digital communication protocol used by EPS systems, there is an increase in the system's phase lag. When the phase compensation amount is increased in order to have an equal phase margin, the phase lag in a specified frequency range (generally 10 Hz and lower) increases and the responsiveness decreases. When it comes to achieving stability on a par with conventional systems, therefore, enhancing responsiveness becomes an issue for EPS systems that include a digital delay.

The present research addresses the enhancement of responsiveness in EPS systems equipped with digital torque sensors, which can be expected to see more widespread use in the future. A model was created and used to determine the target value for EPS system responsiveness, and a method for designing control to achieve responsiveness on a par with systems that do not experience lag was proposed. The influence on vehicle characteristics from an EPS system designed using the proposed method was confirmed. The validity of this approach was successfully confirmed and so is reported here.

EPS control design is determined by the frequency response of the motor current loop and the frequency response of the torque loop. The PI control gain in the current loop is adjusted in advance so that the motor current is made to respond up to frequencies that are higher than the torque loop. This conceptual approach is considered to be also applicable to vehicle performance design. In other words, if the EPS system can be made to have a responsiveness sufficiently higher than other design factors, then it is not necessary to adjust the responsiveness of the EPS individually, and it should be possible to allow a degree of freedom for suspension geometry and tires that make a large contribution to performance design. For the EPS evaluation index, therefore, it was decided to use the transmission characteristic of a closed loop with steering wheel torque as input and rack force with the rack end fixed as output. It will be possible to achieve responsiveness that is on a par with systems that do not include a digital delay by means of this index if the open loop is given the same stability, the closed-loop gain at the resonance point in the vicinity of 20 Hz is reduced, and compensator characteristics can be found that do not produce phase lag in the frequency range up to the 5.5-Hz resonance point, which contributes greatly to steering feel.

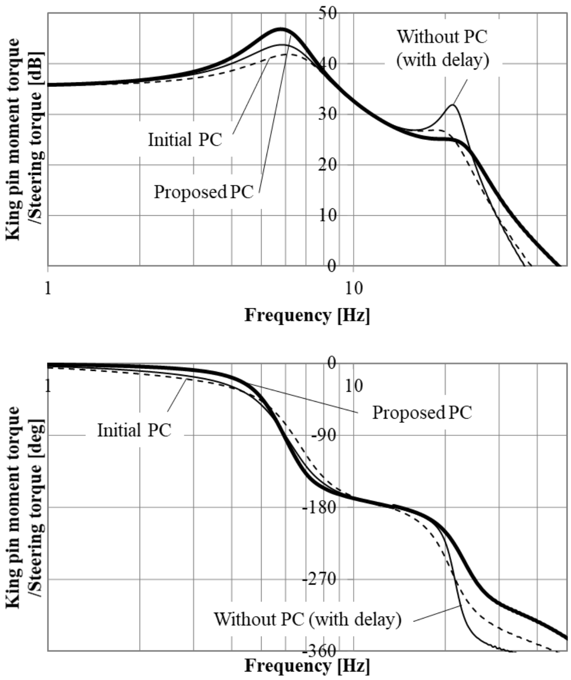

Fig. 1 Evaluation index of closed loop characteristic with Phase Compensation

A model of an EPS system equipped with a digital torque sensor that includes digital delay was created and its validity was verified using an actual EPS system. The use of the created model to enhance responsiveness was also examined and yielded the following findings.

1. When the evaluation index for EPS system responsiveness is the rack force with rack end fixed taken as the output with respect to the torque input, the low-frequency range is influenced by the compensator characteristic that is provided to the closed loop. For this reason, the responsiveness can be enhanced by removing the phase lag caused by the compensator at resonance points at 5.5 Hz and below.

2. Compensator phase lag at low frequencies can be reduced by combining a compensator that advances the phase from frequencies below 10 Hz, where phase lag due to digital delay emerges, with a compensator that provides attenuation at the poles of the transfer function.