# Parameter Design and Tuning Tool for Electric Power Steering System

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*Installation of Electric Power Steering systems (EPS) for automobiles has expanded rapidly in the world thanks to its advantages in energy efficiency/saving. Such trend has been enhanced owing to its easiness of realizing integrated control with brakes and lane-keeping assistance. Moreover, automakers require fitting of the system as well as tuning of steering feeling for the vehicles under development. In accordance with further increase of EPS installation, vehicle types to be tuned increase. The system tuning has to be carried out efficiently in short period of time, although the skill for achieving this requires so much experience. In accordance with this environment, tools to support easy designing of the control parameters and efficient system tuning have been developed.*

***Key Words***: *power steering, parameter design, tuning, fitting*

## 1. Introduction

Installation of electric power steering systems (hereinafter called EPS) has expanded rapidly by world automakers due to their superior energy efficiency and energy conservation. Recently, installation of EPS has been further increasing due to its easy integration with brake and lane keeping guidance controls.

And also, in more automakers, EPS are developed in a way different from the conventional one. Specifically, more EPS are developed as the entire systems by presenting their specifications to suppliers. In such development, EPS system needs to be examined and established with regards to the mounting to the vehicle body, the tuning of the system to each developed vehicle, and also to the tuning of steering feeling.

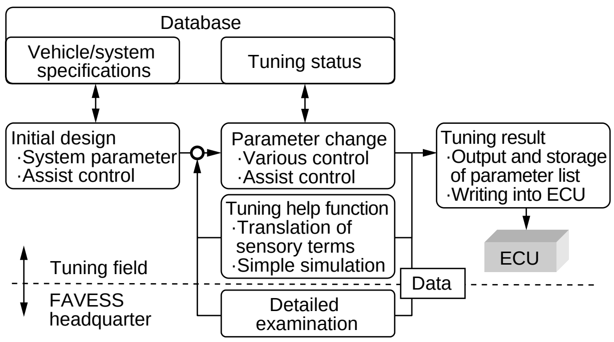
Expansion of the installation of EPS means an increase in vehicle types to be tuned. In order to cope with this trend, an actual vehicle tuning process must be completed efficiently in shorter time. However, a conventional actual vehicle tuning mainly by sensory evaluation requires long tuning time that differs depending on the experience of an evaluator.

In order to reduce the tuning time, it is important for an evaluator having less tuning experience to provide a function for easily calculating an initial design value and/or a function for reducing human errors. At the same time, it is important for an evaluator having much tuning experience to provide a function for easily and efficiently performing operations involved with the tuning for EPS.

In accordance with these needs, FAVESS has developed the tools to support easy designing of the control parameters and efficient system tuning (hereinafter simply called tuning tool). This paper presents the details.

## 2. Outline of Specification of Tuning Tool

**Figure 1** shows the composition and details of the tuning tool. Various pieces of information are added to the database and the initial design is carried out by using the data. In the parameter change section, the initial design values are tuned by changing parameters. The effect of changing parameters can be checked by a simple simulation function. When steering feeling cannot be tuned smoothly, then a help function can be used to find how. The tuning result is written to an ECU via communication. The result also can be added to the specification, etc. to eliminate human errors.




| Items | Details |
|---|---|
| Database | Specifications and tuning status etc. are recorded |
| Initial design | Initial design which is based on the specifications and actual measurement values |
| Parameter change | Function to change parameters |
| Tuning help | Translation from sensory terms into control<br>Simple calculation of steering feeling<br>Detailed examination is performed by FAVESS |
| Tuning result | Preparation of parameter data to be transferred to ECU<br>Function to output and store the tuning result |

**Fig. 1** Tool composition

## 3. Database

The database was compiled for centrally managing the information such as vehicle/system specifications used for design, tuning status and comments.

**Figure 2** shows the first page of the input screen in the database. Vehicle specifications, column specifications, gear specifications, torque sensor specifications, and the version of the software product can be stored. These values are used to design parameters. The input screen has the second page where shipment records of systems can be stored.

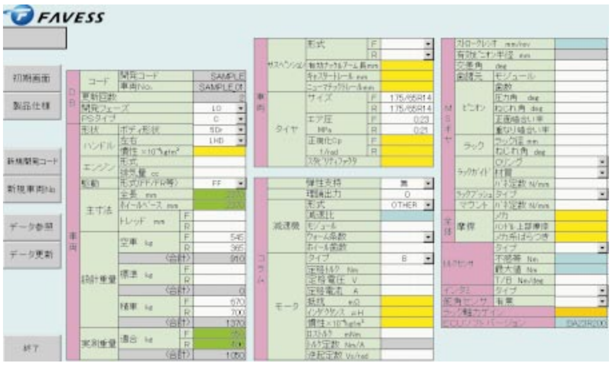



**Fig. 2** Data base input screen

## 4. Initial Design

### 4. 1 Design of System Parameter

### 4. 1. 1 PI Control

**Figure 3** is a block diagram of the current control section. There are various methods to control the current. Here we introduce a case when general PI control is used. PI parameters which are based on motor specifications (inductance, resistance), and response frequency are designed. This tool has eliminated the conventional performance examination which is based on step response and/or frequency response.

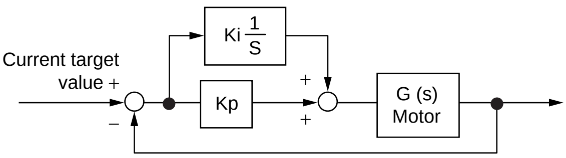



**Fig. 3** Block diagram of current control

**Figure 4** shows the design screen of PI control. When motor specifications are added in this screen, the slider of section "A" in **Fig. 4** is used to check the zero-pole layout and Bode plot is used to provide adjustment for preventing the step response from having fluctuation by checking the system stability and responsiveness.

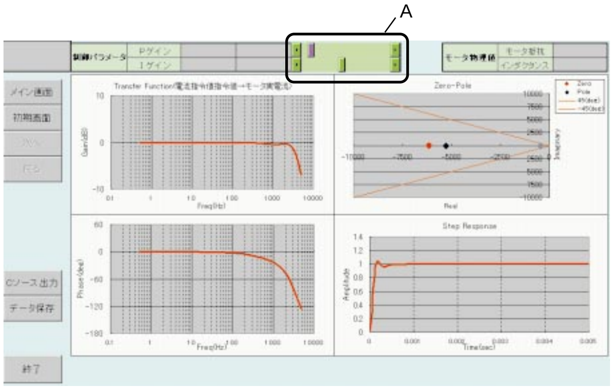



**Fig. 4** PI control design screen

### 4. 1. 2 Phase Compensation

EPS includes a low rigidity torsion bar (hereinafter simply called T/B). A large phase difference between the upper and lower parts of T/B may cause vibration to the system. Phase compensation is provided to adjust the frequency characteristic of the phase of the lower part of T/B against the upper part of T/B, secure the system stability, and to avoid the vibration.

**Figure 5** is a block diagram of the torque loop.

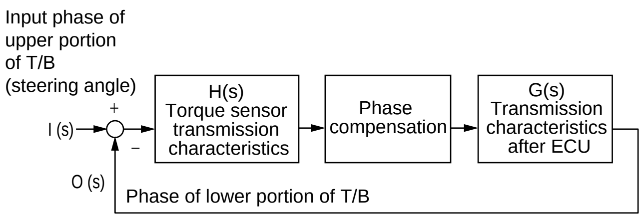



**Fig. 5** Block diagram of torque major loop

**Figure 6** shows the screen for designing the phase compensation. Characteristics of the phase compensation filter are adjusted by the slider of the section "A" while checking the Bode plot of the section "B" in **Fig. 6**. Next, the optimal characteristics design is provided while checking via the section "C" whether the stability is secured or not.

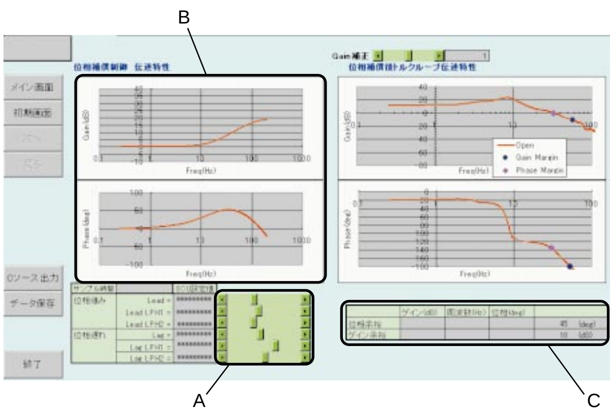



**Fig. 6** Phase compensation design screen

## 4. 2 Design of Assist Control

### 4. 2. 1 Assist Control Configuration

**Figure 7** shows the representative assist control configuration. Here describes the design tool for basic assist control and damping control.

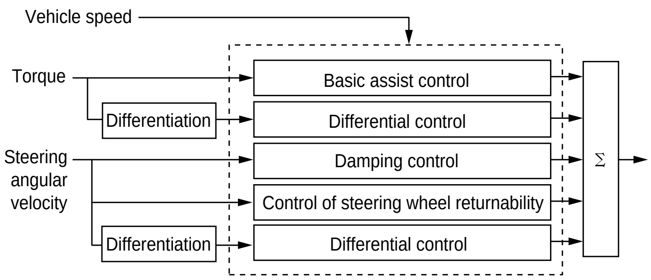



**Fig. 7** Composition of assist controls

### 4. 2. 2 Basic Assist Control

Basic assist control determines the static steering force. The assist torque $T_a$ can be calculated by the formula (1) when the friction and efficiency are ignored.

$$T_a = RF \cdot R_p - T_h \tag{1}$$

where "$RF$" is the rack force, "$R_p$" is the effective pinion radius, and "$T_h$" is the torque loaded by a driver on steering wheel.

In the low torque range, the actually measured rack force is approximated by the steering wheel torque as $RF = aT_h$. Then, the formula (2) is used to calculate the assist torque.

$$T_a = (aR_p - 1)\ T_h \tag{2}$$

In the high torque range, the actually measured rack force is approximated by the higher-degree formula to similarly calculate the assist torque.

Initial design is performed for the vehicle speed of 100km/h first. **Figure 8** shows the rack force at a certain steering angle when vehicle speed is changed. As the rack force rapidly increases at the vehicle speed equal to or lower than 20km/h, the design value at low speed is compensated in accordance with this increased amount.

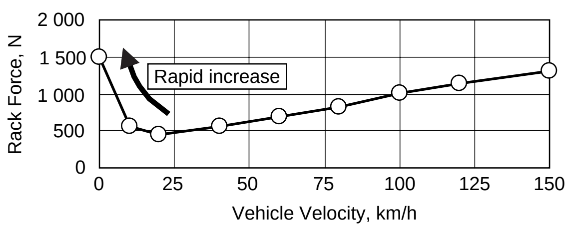



**Fig. 8** Rack force on vehicle velocity change

**Figure 9** shows the design screen of basic assist control. When actual measurement data is inputted, the assist map is calculated automatically. Data for the friction, torque sensor specification, or the like is quoted from the database automatically.

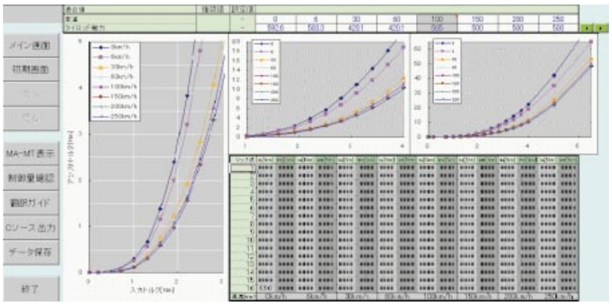


**Fig. 9** Base assist control design screen

### 4. 2. 3 Damping Control

EPS is free from viscosity resistance, such as the pipeline resistance or the orifice resistance caused in the cylinder, valve, piping or the like of the hydraulic power steering. The damping control provides the assist equivalent to the viscosity resistance in accordance with the steering angular velocity and in the direction opposite to the steering angular velocity for improving the convergence and stability of the vehicle.

This tool provides various compensations based on the calculation values of the viscosity resistance of the standard-size hydraulic power steering. **Figure 10** shows a reference amount of damping control.

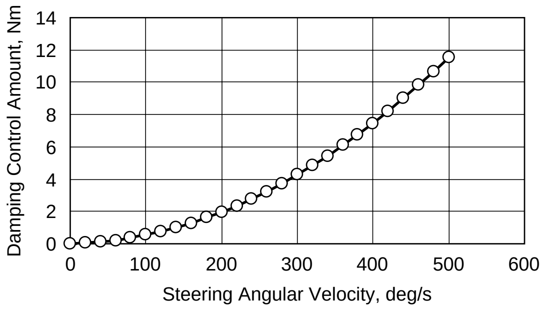



**Fig. 10** Reference damping control amount

When the dynamic equation of the rotational system of a vehicle is represented by the inertia "$I$" viscosity term "$C$" and spring term "$K$" then the viscosity term "$C$" can be represented by the formula (3).

$$C = \zeta / \sqrt{4IK} \tag{3}$$

where "$\zeta$" represents the damping coefficient that is determined as 0.6 based on the stabilization time and fast responsiveness. The control amount is compensated depending on the difference between the inertia "$I$" and the spring term "$K$." By calculating the ratio of the reference viscosity term "$C_0$" to the viscosity term "$C_1$" in the conditions to be compensated, the amount to be compensated can be calculated.

**Figure 11** shows the design screen of damping control. Vehicle specifications in the database are used to automatically calculate the control amount and the vehicle speed coefficient.

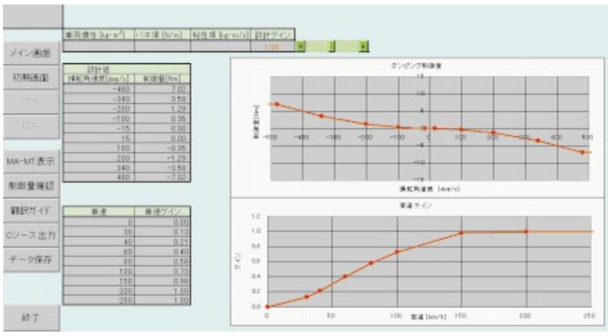


**Fig. 11** Damping control design screen

## 5. Parameter Change

When the feeling is tuned, each control parameter is subjected to fine tuning. **Figure 12** shows the main screen through which parameters are changed. This screen displays main information and representative tuning parameters.

When parameters are actually changed, the main screen is switched to each control screen to change the parameters.

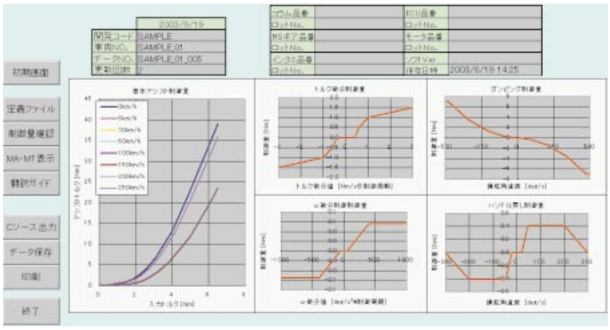


**Fig. 12** Main screen

## 6. Tuning Help Function

### 6. 1 Translation Functions for Terms of Steering Feeling

A user having less tuning experience lacks knowledge about the definitions of sensory terms (requirements) for tuning used by an evaluator. In order to allow the user to find an optimal control as soon as possible, the sensory term translation function summarizing the knowledge for tuning terms is provided.

**Figure 13** shows an example of the screen. In **Fig. 13**, "selection 1" of the section "A" is used to select the steering range and the sensory term, and "selection 2" of the section "B" displays the corresponding control in an order of the effect. When the corresponding control is selected, then the steering characteristic, control amount, and explanation are displayed.

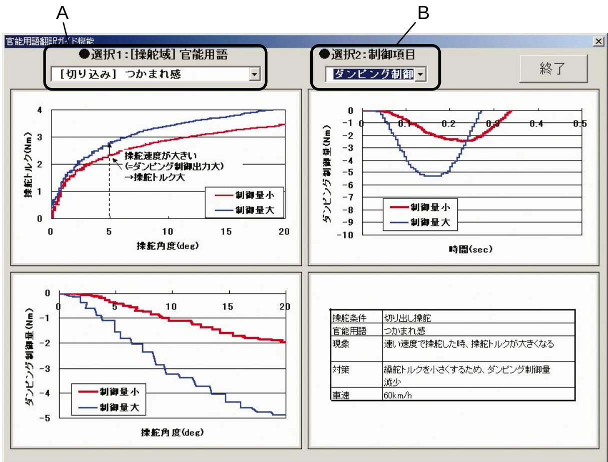



**Fig. 13** Function to translate indication of feeling

### 6. 2 Simple Simulation Function

In order to check the effect by changing the control parameters prior to an actual vehicle evaluation, the simple simulation function is provided. This function allows checking the effect by changing the control parameters based on the parameters and tuning parameters in the inputted database. **Figure 14** shows an example of the result of the simple simulation of the steering angle-steering torque characteristics.

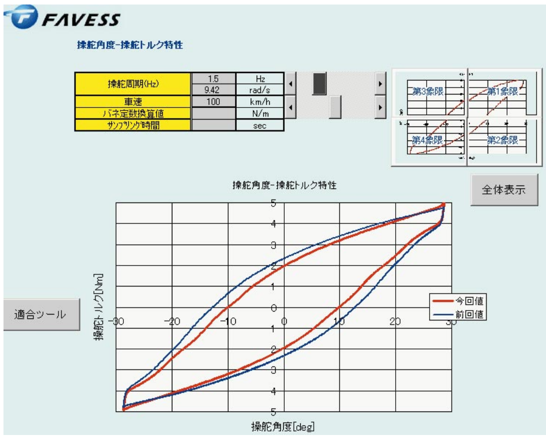



**Fig. 14** Simple simulation screen

### 6. 3 Detailed Examination and Simulation

When an evaluator finds a problem that cannot be solved at the tuning site, the tuning parameters and the result of measuring the control status are sent to the FAVESS headquarter. There, the data are put into a detailed simulation and examination to provide countermeasures for the evaluator at the site.

## 7. Tuning Result

### 7. 1 Writing Tuning Parameters into ECU

The tuning result is automatically sent and stored to ECU via communication by only clicking a "transfer" button. Normal parameter tuning is provided in the RAM region of CPU and thus is removed when the ignition is changed to off. To prevent this, a function is also prepared for the flash writing of the tuning parameters to CPU.

### 7. 2 Storage and Output of Specification

The tuning result can be stored anytime. Past parameters also can be called anytime.

When the tuning operation is completed, then the parameter list and/or specification is directly retrieved by the tuning tool. The displayed result is presented to the customer and/or person responsible for the software. Such a direct output can avoid human errors such as transcription error and also can reduce manhours.

## 8. Conclusion

The tool for control parameter design and parameter tuning has been developed to cope with the expanded installation of EPS and an increased number of vehicles to be tuned. This tool has allowed even an inexperienced user to design parameters easily. At the same time, this tool has allowed an experienced user to reduce the tuning time by improved efficiency.

However, considering the expanding installation of EPS in the future, we are developing the next version of the tool for further improving the functions.

The next version has an intention of further improving the measurement function to provide detailed measurement of the control status of the interior of ECU by using the high-speed bus communication. The next version also includes the AD input system through which the control status of the interior of ECU and analog data (e.g., data by steering angle gauge, yaw rate) can be measured in a synchronized manner. **Figure 15** shows the image of the tuning tool of the next version.

The next version is also capable of sharing the data with simulation software such as MATLAB, and makes it possible to perform detailed examination using MATLAB at the tuning site.

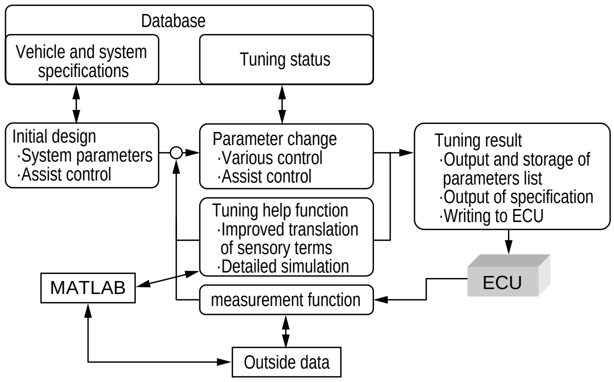



**Fig. 15** Image of next version design and tuning tool

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