Simulation analysis of electric power steering System (EPS) test platform

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Abstract. Based on the principle analysis of the electric power steering system (EPS), a simulation platform for electric power steering system (EPS) test is proposed, and use Matlab/Simulink to build a simulation model of the electric power steering system (EPS) test simulation platform, for the simulation analysis of the electric power steering system under various experimental conditions and working conditions, so as to get the boost current and boost torque needed in various situations, for the design and development of electric power steering systems.

1. Introduction
The assist characteristic curve of the electric power steering system is determined by fitting the experimental data of different vehicle models and different working conditions \cite{1}, in this way, the period of obtaining test data is long, the research and development cost is high, complicated mathematical calculations are required and the accuracy is not high, and the safety hazards of the experimenters increase under complicated vehicle conditions. The electric power steering system test platform is to solve the problem that the experimenters cannot study the dynamic response of the car under extreme conditions or other conditions on the basis of existing conditions, and the effect of the steering system when the vehicle speed, load, and road parameters change influences, therefore, the optimal control strategy and control problem of EPS cannot be obtained \cite{2}. The electric power steering system can more accurately simulate the steering dynamic characteristics of the car under various working conditions, which helps to shorten the design cycle, reduce costs, and ensure the safety of experimenters.

2. Electric power steering system (EPS) test simulation platform
The electric power steering system (EPS) can be said to be the fourth-generation product of the steering system. It improves the shortcomings of the previous generations of steering systems that are inefficient at low speeds and unstable at high speeds \cite{1}, the electric power steering system uses an electric motor as a booster device, and its control device is based on the angle signal, torque signal and engine speed signal from the steering wheel, then determine the size and direction of the motor input current according to the assist table, so that the steering system can achieve a suitable assist effect. The main content of the assist table is the assist torque required by the electric power steering system under any working conditions under the action of the driver's steering wheel angle and torque, that is, the magnitude and direction of the current required by the assist motor. The key components of EPS
system mainly include angle sensor, torque sensor, vehicle speed sensor, booster motor, deceleration mechanism and electric control unit (ECU) etc [3]. Without changing the distribution of the main structure of the electric power assist system, by adding a road simulation platform, a test simulation platform is envisaged to simulate actual conditions, obtaining electric power steering under the action of the road surface (torque) and the driver’s steering wheel Parameters such as assist current corresponding to the system, therefore, an excellent driving feeling can be obtained while ensuring that the driver is driving safely.

The key components of the test simulation platform mainly include angle sensors, servo amplifiers (AMP), servo valves, hydraulic motors, rack and pinion boxes, steering shafts etc, the system’s power unit uses a hydraulic motor. The purpose of this is to not only bear the weight of the platform and the car, but also truly simulate the real situation of the electric power steering system under the action of factors such as the road surface. Schematic diagram of electric power steering system (EPS) test simulation platform as show in Fig. 1:

![Figure 1. Schematic diagram of electric power steering system test simulation platform.](image)

3. Electric power steering system (EPS) test simulation platform model

The working principle of the test platform is that when the steering wheel rotates, the angle and torque sensors will not only transmit signals to the electric power steering system control unit, but also transmit their signals to the test platform control unit, after the test platform control unit receives the signal and the vehicle conditions and working conditions to be simulated, it outputs the signal through its own algorithm, the hydraulic motor is controlled by the servo valve to accurately simulate the road conditions. The rack and pinion box transfers the road steering resistance torque received by the tires through the torque sensor on the steering shaft, after obtaining the torque signal, the control unit of the electric power steering system can obtain the magnitude and direction of the assist torque and assist current after satisfying the angle, road feel and other parameters. The schematic diagram of the experimental simulation platform is shown in Figure. 2:

![Figure 2. Electric power steering system (EPS) test simulation platform schematic diagram](image)
3.1. Angle output device

It is well known that the steering of a car is controlled by the steering wheel. In this model, we use an angle output device to replace the steering wheel. The angle output device model includes angle unit voltage and rotation angle terms and parameters, while other terms are also omitted in the model. This model takes into account the unit voltage of the angle output unit and the angle of the steering wheel (rotation angle), and ignores the influence of friction and other factors of the components. The calculation formula (1) of the angle follower model is as follows:

\[ E = Kp1 \cdot \theta \]  

Where: \( E \) is the input voltage; \( Kp1 \) is the angle unit voltage; \( \theta \) is the rotation angle.

3.2. Servo AMP

Servo AMP is also called a servo amplifier, assuming it is an ideal amplifier, without power loss and time lag. Servo AMP only increases the servo valve current to meet its higher current demand. In order to meet the needs of the servo valve, the dimensionless constant gain (\( Ka1 \)) or servo resistance value (\( R1 \)) of the input voltage and input current is determined. Use the ratio of the two to adjust the input voltage and input current (\( i \)) to meet the requirements of the servo valve, as shown in the mathematical formula (2):

\[ i = \frac{Ka1}{R1} (E - Kp1 \cdot \theta) \]  

3.3. Servo valve model

Servo valve modeling considers its own characteristics, and the model is mainly constructed using the relationship between its output flow (\( Q \)) and its parameters. The unique parameters of this model are: servo valve gain (\( Kv1 \)), servo valve timing (\( Tv1 \)), servo valve flow pressure coefficient (\( C21 \)), servo valve inlet and outlet pressure difference (\( P \)), and internal leakage of the servo motor related to the hydraulic motor Oil pressure difference coefficient (\( C31 \)). The calculation formula (3) of the servo valve model is as follows:

\[ Q = \frac{Kv1}{Tv1 \cdot s + 1} \cdot i - C21 \cdot P - C31 \cdot P \]  

3.4. Hydraulic motor model

Modeling of hydraulic motors can be said to be one of the most important aspects of this system, and it is also a major difficulty. Since hydraulic motors involve many factors and are more susceptible to external factors, once any link is not in place, it will produce large experimental errors, some important parameters are selected for this model: hydraulic motor oil circuit oil pressure coefficient (\( K1 \)), hydraulic motor delivery capacity per revolution (\( Dm1 \)), hydraulic motor output torque (\( T \)), hydraulic motor torque capacity (\( Km1 \)) And hydraulic motor inertia (\( Jm1 \)) and viscous resistance coefficient (\( cf1 \)), based on the relationship between them, the mathematical relationship expression of hydraulic motor is constructed.

The calculation formulas (4) and (5) of the hydraulic motor model are as follows:

\[ P = \frac{1}{K1 \cdot s} (Q - Dm1 \cdot s \cdot \theta) \]  

\[ T = Km1 \cdot P \]  

Assuming that there is a mathematical relationship between the rotation angle and the inertia of the hydraulic motor, the output torque, and the resistance coefficient of itself and the viscosity (6):

\[ \theta = \frac{1}{Jm1 \cdot s^2} (T - cf1 \cdot s \cdot \theta) \]
3.5. Gear rack box, steering shaft

The rack and pinion box is a transmission device that converts rotary motion into linear motion, assuming that it is an ideal device ignoring the influence of factors such as friction, energy loss, etc., its model can be simply represented by a gain; The steering shaft only plays a transmission role in the system, so it is also represented by a gain with reference to the rack and pinion model.

The simulation model of the electric power steering system (EPS) test simulation platform is shown in Figure 3:

4. Simulation analysis based on Matlab

Through the above analysis, we got the simulation model of the electric power steering system (EPS) test simulation platform. The PID control method in Simulink is used in the model to control the servo valve to control the hydraulic motor. While the hydraulic motor is compensated for factors such as leakage and friction, a model from the steering shaft to the hydraulic The feedback of motor model and road torque input makes it more accurate. When under normal road conditions and normal vehicle conditions, a sinusoidal input signal is applied to the steering wheel to simulate, and the required experimental data is obtained. The simulation results of the electric power steering system (EPS) test simulation platform are shown in the following figure:

Figures 4 and 5.
When it is necessary to obtain the assist torque and assist current of the electric power steering system under other working conditions and vehicle conditions, only need to change part of the parameters of the test simulation platform model to correspond to the corresponding working conditions and vehicle conditions, and the required data can be obtained.

5. Conclusion

The use of the electric power steering system (EPS) test simulation platform can enable automobile development and design engineers to obtain experimental data of various types of cars in various real simulation situations with a small economic budget and a very short time, this will help reduce economic costs and increase the development cycle, while also greatly improving the safety factor of the electric power steering system (EPS), simulink is used to construct the simulation model of the electric power steering system (EPS) test simulation platform, this method not only verifies the design idea but also avoids complicated mathematical calculations, thereby saving the development cost and time of the electric power steering system (EPS) test simulation platform.

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