EHPS Handling Stability Analysis of Electric Bus Based on System Identification Method

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Abstract. Electric hydraulic assist force steering system (EHPS system) is the steering system of electric bus, this paper presents a method of EHPS handling stability analysis based on system identification method according to the handling stability of EHPS system for electric bus. The simulation model of electro-hydraulic assist force steering system EHPS is established by using the software AMESim, and making a quantitative analysis on the characteristics of the electric assist force assisted steering system, the assist force response and stability. At the same time, we study the stability of vehicle, including hunting, transient response, return experiment, the results show that the HPS and EHPS by comparing the simulation: It improves the portability, road sense, transient response and return performance after loading the system, which verify the effectiveness of the control strategy that improves vehicle steering performance, and it provides the basis for the optimization of control methods in the future.

Keywords: EHPS; handling stability analysis; AMESim; control strategy; electric bus

1. Introduction
With the development of system identification methods, the method of identification modeling has been widely used in the field of vehicle engineering. It proved to be effective that the off-line identification method based on neural network and the online identification method based on Delft tire model in the identification of road friction coefficient. It is necessary to use the software AMESim to establish the simulation model of electro-hydraulic assist force steering system EHPS, which makes a quantitative analysis of the characteristics of assist force assist, assist force response and stability of the electric hydraulic assist force steering system. The vehicle handling stability performance is studied to verify the effectiveness of the control strategy for improving vehicle steering performance, and which provide the basis for the optimization of control methods in the future.

2. EHPS system model based on AMESim
The input signal simulation model is shown in Figure 1.

Figure 1. Simulation Module of Input Signal
When the driver steers the steering wheel, the steering wheel can be viewed in two ways, angle input and force input. When the vehicle is at low speed, the input port is used, and the force input port is used at high speed.

![Figure 2. Simulation Module of Rotation Valve](image1)

The model of Rotation Valve is shown in Figure 2. Torsional spring simulation module with proper stiffness is used to simulate the torsion bar. The upper and lower ends of the torsion bar are respectively provided with an angular displacement signal output module, the difference between the output signals of the two modules is used as the deformation signal of the torsion bar. The signal is then transferred to the model of rotation valve.

![Figure 3. Simulation Module of Tyre](image2)

In the simulation, the sliding friction force in the tire simulation module is changed according to the formula, so we can simulate the change of the driving resistance during the driving process, as shown in Figure 3.

The control model of the motor is established according to the dynamic mathematical model of the motor, and the requirement of motor control is accurate and quick response.

The steering resistance is different when the vehicle is traveling at different speeds, the current is different because the motor current is linear with the load, the voltage drop of the armature resistance varies with the current, so that the back EMF is different at different speeds. That is to say, the relationship between the motor voltage and the motor speed is not constant but with the speed change, so in order to meet the requirements of motor speed control, the use of the speed loop closed loop control method.

![Figure 4. Simulation Module of double closed-loop motor control](image3)

Control of the motor using the speed loop and current loop that called double closed loop PID speed control system, as shown in Figure 4.

The motor speed is controlled by controlling the motor voltage through using the DC motor to drive the hydraulic pump, it can limit the maximum current to prevent the gear pump gear being broken and it also avoid the motor being damaged when the current is surged. At the same time, the motor speed feedback signal and the current feedback signal are analyzed to determine the control voltage.
3. EHPS system handling stability analysis
In order to improve the steering performance of the EHPS system compared with the HPS system, the two steering systems are simulated and the simulation results are compared.

3.1 Simulation and analysis of assist force response characteristics
Assist force response characteristics include two aspects: assist force response speed and stability. Due to the existence of the valve structure, the bus EHPS and HPS system can be based on the mechanical structure to enter the booster cylinder hydraulic oil flow changes according to the change of the steering wheel speed. Therefore, we only need to verify the control strategy of the bus EHPS system, in which the control adjustment that the relationship between assist force size and steering wheel speed is appropriate or not.

We set the speed of 50km/h in the simulation, respectively, with 120deg/s, 360 deg/s, 500 deg/s, 720 deg/s, 800 deg/s rotating speed uniform steering wheel. And we get the curve of simulation of hydraulic assist force in various steering wheel speed change, that is, the assist force response curve, as shown in Figure 6.

![Figure 6. Assist Force on Rack with Various Steering Speed](image)

In response time (the first time of reach steady state) and overshoot (maximum assist force / steady state) indicate the assist force response and stability. As shown in Figure 6, hit the steering wheel, the response time is less than 0.3s, and the maximum overshoot does not exceed 10% of the steady-state value. It shows that the assist force response and stability are good.
3.2 Simulation and analysis of the middle position handling stability
Analyzing the high speed steering and steering wheel force through the simulation of snake working condition. The maximum speed of 70%, and rounding an integer multiple of 10, in the simulation, the model keeps the speed of 90km/h in serpentine road condition as a sinusoidal curve. The period of sine motion is 5S, and the maximum lateral acceleration is 0.2g. Finally, we get simulation of the steering wheel torque and lateral acceleration curve, as shown in Figure 7.

![Figure 7. Handwheel Torque vs Lateral Acceleration](image)

3.3 Simulation analysis of transient response
Simulation and analysis of vehicle transient response performance is based on steering wheel angle step input. The maximum speed of 70%, and rounding an integer multiple of 10, in the simulation, the model is driven by 90km/h speed. The steering wheel is applied to a ramp angle input of the 20 rad/s to produce a 30 degree angle, and the vehicle yaw rate variation curve is shown in figure 8.
The simulation results are shown in table 1, the reaction time is called as the time when the yaw rate of the vehicle reaches the steady yaw rate for the first time. We can see the result through comparing simulation of EHPS and HPS. The vehicle loaded with EHPS has a shorter reaction time, and the driver feels more responsive; The steady yaw rate is small, which increases the vehicle understeer.

![Figure 8. Yaw-rate of angle step input](image)

3.4 Simulation and analysis of return performance
The maximum speed of 70%, and rounding an integer multiple of 10, in the simulation, the model is driven by 90km/h speed. Turning the steering wheel to achieve lateral acceleration of 20 m/s², loosen the steering wheel suddenly after it is stable. We set the steering wheel torque to zero through in the simulation. Recording 4 seconds after the release of the movement process. Then we analyse the relationship between yaw velocity and time, as shown in figure 9. Compared with the EHPS and HPS residual yaw rate can be seen, after loading EHPS, the performance of high speed recovery is significantly improved, and which is near completely return-to-center.
4. Conclusion
The simulation model of electro-hydraulic power steering system EHPS is established by using the software AMESim, and the paper makes a quantitative analysis of the assist force characteristics, assist force response and stability of the electric hydraulic power steering system, we also research the stability of vehicle, including hunting, transient response, return-to-center experiment, the results show that the system can improve the portability, road sense, transient response and return-to-return performance by comparing the simulation results of HPS and EHPS, which verify the effectiveness of the control strategy in improving the steering performance of the vehicle and provides the basis for the optimization of the control method in the future.

Acknowledgment
Funding from the National Natural Science Foundation of China (Grant No: 61503163), the “333 project” of Jiangsu Province (Grant No: BRA2016440) and the six talent peaks project in Jiangsu Province (Grant No: ZBZZ-024) are gratefully acknowledged, Changzhou Science and Technology Support Plan Project(CE20150084), Ministry of Housing and Urban-Rural Science and Technology Program(KYZB16002).

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