ISSN 2706-655X Vol.3, Issue 3: 11-16, DOI: 10.25236/IJFET.2021.030303

Current Situation Analysis and Future Development Trend of Automotive Engineering Control System

Zeming Tao*

Shouguang Institute of Science and Technology of Shouguang City, Shandong Province, China
**Corresponding author e-mail: t15689285207@gmail.com*

Abstract: *With the development of electronic technology, the application of electronic control system (CS) in automobile is more and more, especially the dynamic CS. As a typical dynamic CS, ESC not only plays a key role in the field of active safety, but also is the key executive layer of intelligent driving system. Vehicle state parameters are the basis of ESC control and have a direct impact on the intervention effect of ESC related functions. From the cost of engineering application, a considerable part of the state parameters can not be directly measured by sensors. Therefore, the real-time and accurate estimation of state parameters becomes the key to limit the industrial application of ESC. At present, the key technology has not been mastered in the research and industrial application of ESC control in China, which makes the developed ESC products difficult to meet the needs of industrialization. This paper mainly studies the automotive engineering(AE) CS. Through the analysis of the ESC dynamics CS, we can understand the functional modules of the dynamics CS, and elaborate the control scheme of the ESC dynamics CS. We also study the vehicle yaw rate algorithm and analyze the vehicle yaw steering wheel angle and speed by chart analysis method. The experimental results show that the natural frequency of vehicle yaw is generally between 0.5Hz and 0.7hz. Compared with the single sinusoidal input test, the steering wheel angle required to excite the vehicle yaw rate response is smaller in the sinusoidal stagnation test. At 0.5Hz, the sinusoidal stagnation test needs to swing 130 degrees, while the single sinusoidal input test needs to swing 200 degrees.*

Keywords: *Control System, Automotive Engineering, Status Analysis, Development Trend*

1. Introduction

The safety of automobile has been concerned by the world since its birth, because it is not only related to the safety of people's lives and property, but also affects people's living environment [1-2]. In recent years, with the gradual entry of cars into ordinary people's families, leading to the non professionalization of drivers, traffic safety has become a problem in front of everyone, affecting everyone's life [3-4]. Automotive electronic stability CS (ESC) is a typical dynamic CS, and as a representative of automotive active safety system, it plays an important role in daily driving [5-6]. It is an indisputable fact that ESC can effectively reduce the traffic accidents caused by car out of control and reduce the casualties of passengers and property in traffic accidents. With the continuous improvement of people's safety awareness and the increasingly strict national regulations and standards, automobile manufacturers continue to optimize and transform automobile safety technology in the production process, and strive to ensure vehicle safety to the greatest extent in the production process [7-8]. Because ESC system can improve the driving stability and driving safety of vehicles under various driving conditions, it has become one of the most important active safety systems since its birth, and gradually become one of the standard safety devices of vehicles [9-10].

In the research of AE electronic stability CS, many scholars at home and abroad have studied it and achieved good results. Ueda s and others put forward the integrated control method to control the handling stability of the vehicle, that is, the ABS, ASR, suspension and steering system are integrated to control, which provides a reliable guarantee for the safety of vehicle driving [11]. Based on RLS estimation method and longitudinal dynamics and acceleration deviation slope estimation model, Hakim a e et al. Carried out joint research on mass estimation and road slope estimation of truck. It can be seen from the research results that when the road slope changes little, only the longitudinal dynamic model can meet the requirements, but when the road slope changes rapidly, the estimation result of the joint slope estimation model is more accurate [12].

This paper mainly studies the AE CS. Through the analysis of the ESC dynamic CS, we can understand the functional modules of the dynamic CS, including the information interface module, the parameter estimation module, the functional logic module, the functional coordination module, the pressure control module and the functional safety module. This paper describes the control scheme of ESC dynamic CS, understands its basic control principle, control target object, and studies its vehicle yaw rate algorithm. It is found that the greater the yaw moment is, the earlier the ESC dynamic CS intervenes to protect vehicle safety. Based on big data, this paper uses data collection to analyze the ESC loading rate, and uses chart analysis method to understand the rising of ESC loading rate and the analysis of vehicle yaw steering wheel angle and speed.

2. Vehicle Dynamics Control System

2.1 Function Module of Dynamics CS

(1) Signal interface module

The signal interface module includes the input and output signals of ESC and external modules, which are divided into sensor signal and can bus signal. It calculates, processes and compensates the measured value of the sensor. The signal interface is composed of a single module to realize the separation between the basic software and the application software. The communication between modules is realized through the standard entrance function, which is conducive to the transplantation of software.

(2) Parameter estimation module

The parameter estimation module includes the key parameter estimation in ESC system, including reference speed estimation, road adhesion coefficient estimation, centroid side deflection angle and wheel side deflection angle estimation, tire stress estimation, vehicle mass and centroid position change estimation, and vehicle stability behavior. The estimation of different parameters will affect each other, and these parameters have a great influence on the triggering and control of the dynamic characteristics and functions of the vehicle.

(3) Functional logic module

The function module includes the control algorithm of main functions such as EBD, ABS, TCS and VDC, and other additional functions such as brake assist, brake characteristic improvement, auxiliary deceleration and auxiliary speed control. Different functions have different priorities and different control targets. For example, the auxiliary speed control function needs to control the current vehicle speed, the brake assist and brake characteristic improvement function needs to control the longitudinal acceleration, in addition, AVH and other functions also need to coordinate the longitudinal force.

(4) Function module coordination module

The purpose of function coordination module is to get the final target torque according to the priority of function and different coordination quantity when multiple functions are triggered at the same time. The function coordination module can select the most suitable function to release and coordinate the optimal control quantity to avoid fighting between different functions.

(5) Pressure control module

The pressure control module includes the estimation and control of the wheel cylinder pressure. According to the characteristics of the brake and HCU, the PWM command of the solenoid valve and the switch command of the motor are calculated.

(6) Functional safety module

Whether it is the measurement signal or the estimation signal, it can not guarantee that all the values are correct or credible in the real vehicle. When there is an error value in a certain period of time, it may cause the wrong trigger of the function, leading to serious consequences. Therefore, it is necessary to monitor and verify all the signals, find out the wrong signals in time, and ensure the safety and reliability of all the systems, which is the task of the functional safety module.

2.2 Control Scheme of Dynamic CS

ESC system contains all the control functions of ABS and TCS. When the vehicle is running, ESC system continuously detects the driver input and the actual driving condition and state of the vehicle through the sensor system, and judges the detected driver input and vehicle state, compares and makes corresponding response according to the expected vehicle motion state and the actual vehicle motion state. In order to meet the requirements of vehicle stability control, a hierarchical CS is adopted in ESC system. On the one hand, the information input of the whole CS comes from the sensors installed on the vehicle, on the other hand, it comes from the state parameter estimator. This is because the important state parameters such as longitudinal speed, sideslip angle and road adhesion coefficient needed in ESC system control are difficult to be directly measured by on-board sensors, so they need to be estimated on the basis of measurable signals. The deviation between the driver's expected motion and the actual motion calculated by the input information is taken as the input of the upper motion controller. The upper motion controller is responsible for calculating the nominal yaw moment needed to eliminate the motion deviation and distributing the nominal yaw moment to the braking force of each wheel. The nominal braking pressure of each wheel can be calculated by the braking force on each wheel. The lower layer executive controller controls the braking pressure on the bottom layer, and finally applies the force on the vehicle system through the road surface. Although different ESC system manufacturers and automobile manufacturers use different names for ESC system, it is only in the design goal, control strategy and pursuit of ESC system.

2.3 CS Evaluation Parameter Algorithm

The combined sensor signal includes longitudinal acceleration signal, lateral acceleration signal and yaw rate signal. The value measured by the external combined sensor can be received through CAN bus. Because the installation position of the sensor is not necessarily in the center of mass, coordinate transformation is needed. When the vehicle is turning (without considering the rear wheel steering), the yaw rate of the vehicle is:

$$\omega = \frac{u}{L} * \tan\delta \tag{1}$$

Where ω is the yaw rate, u is the vehicle speed, L is the wheelbase, and δ is the front wheel angle,the specific values are:

$$\delta = \frac{180}{\pi} * \frac{\alpha(t)}{i_{steer}} \tag{2}$$

Where $\alpha(t)$ is the steering wheel angle input, i_{steer} is the steering gear speed ratio, and the vehicle yaw moment Mz formula is:

$$M_z = I_z\omega = \frac{I_z u}{L * i_{steer}} * \frac{1}{\cos^2(\alpha(t)/i_{steer})} * \alpha(t) \tag{3}$$

According to the formula, the yaw moment Mz needed to keep the vehicle running according to the specified route can be calculated under different steering wheel angle input characteristics. When the vehicle speed and steering angle amplitude are the same, the greater the yaw moment Mz is, the easier it is to stimulate the vehicle's ultimate yaw rate response, and the ESC system can intervene earlier.

3. Experimental Study

3.1 Subjects

In this paper, the AE CS is studied, and the ESC dynamic CS is analyzed. By studying the functional modules of the dynamic CS, the control scheme of the dynamic CS and the CS evaluation parameter algorithm are understood. The development status of the AE CS is studied and its future development trend is prospected.

3.2 Experimental Process Steps

This paper mainly studies the automotive engineering CS. Through the analysis of the ESC dynamic CS, we can understand the functional modules of the dynamic CS, including the information

ISSN 2706-655X Vol.3, Issue 3: 11-16, DOI: 10.25236/IJFET.2021.030303

interface module, the parameter estimation module, the functional logic module, the functional coordination module, the pressure control module and the functional safety module. This paper describes the control scheme of ESC dynamic CS, understands its basic control principle, control target object, and studies its vehicle yaw rate algorithm. It is found that the greater the yaw moment is, the earlier the ESC dynamic CS intervenes to protect vehicle safety. Based on big data, this paper uses data collection to analyze the ESC loading rate, and uses chart analysis method to understand the rising of ESC loading rate and the analysis of vehicle yaw steering wheel angle and speed.

4. Experimental Research and Analysis of ESC Vehicle Dynamics CS

4.1 Loading Rate Analysis of ESC CS

The vehicle ESC system can be used to realize the stability control of the vehicle. By controlling the yaw moment generated by the difference between the braking force or driving force of the left and right wheels, the vehicle can be prevented from losing control in the process of turning at high speed or emergency braking. Therefore, the ESC CS can keep the vehicle stable and safe under certain conditions. Based on this, this paper uses data collection and analysis methods to collect the percentage of vehicle ESC loading rate every two years since 2012. The results are shown in Table 1.

Table 1.ESC CS loading rate

years	2012	2014	2016	2018	2020
truck	36	54	85	100	100
Family car	27	39	66	100	100

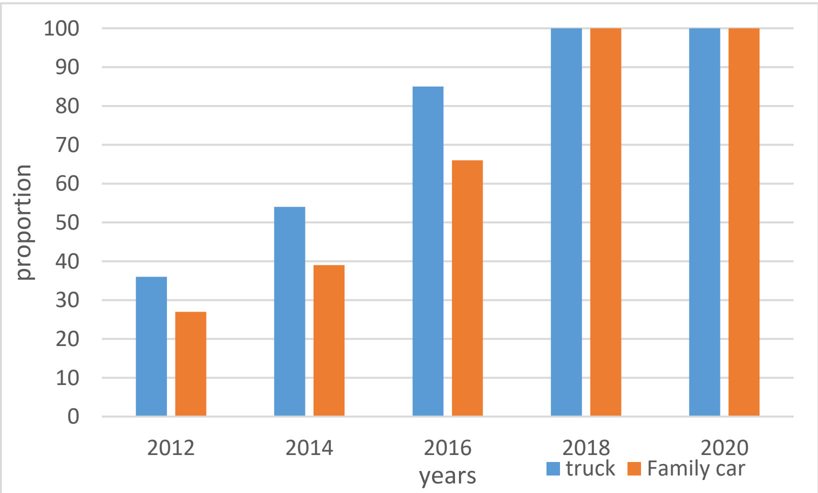

Figure 1 ESC CS loading rate

As can be seen from Figure 1, in the early years, people did not have a strong awareness of the safety performance of the ESC CS, and they did not have a strong concept of equipped with the ESC CS. In 2018, the ESC CS had achieved a 100% loading rate, and people had a basic car safety awareness.

4.2 Vehicle Yaw Steering Wheel Angle and Speed

In order to study the relationship between vehicle yaw steering wheel angle and speed, this paper simulates vehicle speed measurement to study steering wheel angle. As the natural frequency of vehicle yaw is generally between 0.5Hz and 0.7hz, this paper selects vehicle yaw frequency between 0.5 and 0.8hz, and the results are shown in Table 2.

ISSN 2706-655X Vol.3, Issue 3: 11-16, DOI: 10.25236/IJFET.2021.030303

Table 2. Analysis of vehicle yaw steering wheel angle and speed

test method		Test angle
Single sine input	0.5HZ	200
	0.6HZ	240
	0.7HZ	180
	0.8HZ	170
Sine stagnation	0.5HZ	130
	0.7HZ	160

Figure 2 Analysis of vehicle yaw steering wheel angle and speed

As shown in Figure 2, the sine stagnation test requires less steering wheel angles than the single sine input test to stimulate the vehicle yaw rate response. When the sine frequency and the yaw natural frequency are closer, the more likely the vehicle to produce the yaw limit state, and the experimental data show that the sine stagnation input steering test is not sensitive to the natural frequency of the vehicle yaw, the requirements are lower, and the range of applicable vehicle models is wider.

5. Conclusions

The ESC CS of automobile has connected the steering, braking and power systems together. It has been proved to be one of the main active safety technologies to effectively reduce automobile traffic accidents. It is of great significance to carry out the research and evaluation of ESC CS. This paper mainly studies the automotive engineering CS, through the research of ESC dynamics CS analysis, understand the dynamic CS function module. This paper describes the basic control principle of ESC CS, the object of control, and the algorithm of vehicle yaw rate, and the angle and speed of vehicle yaw wheel.

References

[1] Kim S Y, Abbasizadeh H , Ali I , et al. An Inductive 2-D Position Detection IC With 99.8% Accuracy for Automotive EMR Gear Control System[J]. IEEE Transactions on Very Large Scale Integration Systems, 2017, 25(5):1731-1741.
[2] Xiao L, Wu J , Chen X . Teaching Reforms in Automotive Power train and Chassis Control System Experiment[J]. IJARCCE, 2016, 5(9):534-536.
[3] Kami, Buchholz. Continental demonstrates new sensing tech for SAE Level 4 capability[J]. Automotive engineering, 2017, 4(1):8-9.
[4] F Lei, Li T, Wang J , et al. A semi-physical model for pneumatic control valves[J]. Nonlinear Dynamics, 2016, 85(3):1-14.
[5] Chu H , Guo L , Chen H , et al. Optimal car-following control for intelligent vehicles using online

ISSN 2706-655X Vol.3, Issue 3: 11-16, DOI: 10.25236/IJFET.2021.030303

road-slope approximation method[J]. Science China Information Sciences, 2021, 64(1):1-16.

[6] Dellios K, Patsakis C , Polemi D . Automobile 2.0: Reformulating the Automotive Platform as an IT System[J]. It Professional, 2016, 18(5):48-56.

[7] Xiong L, Xu S , Yu Z . Optimization of Hydraulic Pressure Control System of Integrated Electro-hydraulic Brake System Based on Chatter-compensation[J]. Journal of Mechanical Engineering, 2016, 52(12):100-106.

[8] Artono B, Susanto F . LED control system with cayenne framework for the Internet of Things (IoT)[J]. JEECAE (Journal of Electrical Electronics Control and Automotive Engineering), 2017, 2(1):95-100.

[9] Wang Q , Li A , Li Y , et al. Microtension control for a yarn winding system with an IMC PID controller[J]. Mechanics and Industry, 2019, 20(6):609.

[10] Wan J, Canedo A , Faruque M . Cyber–Physical Codesign at the Functional Level for Multidomain Automotive Systems[J]. IEEE Systems Journal, 2017, 11(4):2949-2959.

[11] Ueda S, Wada T . A Haptic Communication Method for A Preceding Vehicle Following System[J]. International Journal of Automotive Engineering, 2016, 7(3):99-105.

[12] Hakim A E, Atmaja A P , Karyawati D . Soil Moisture Controlling Using Wireless Sensor Network System in Smart Agriculture[J]. JEECAE (Journal of Electrical Electronics Control and Automotive Engineering), 2019, 4(1):217-222.