Development and Practice of Control Strategy for Driving Stability of Pure Electric Vehicle

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Abstract

Aiming at the problem of ride comfort control of pure electric vehicles under the conditions of rapid acceleration and deceleration, a vehicle ride comfort control strategy is designed in the paper, which includes accelerator pedal analog signal acquisition circuit design, software filtering, incremental first-order dynamic low-pass filter with accelerator pedal opening, And the target output torque filtering control and a series of strategies. Through a pure electric vehicle road test, the test results show that: this article designed vehicle ride comfort control strategy can make pure electric vehicles in the acceleration and deceleration conditions of vehicle driving without obvious jitter phenomenon.

Keywords

Pure electric vehicle; Drive stability control; First-order dynamic filtering; Torque control

1. Introduction

The pure electric car is a single battery as a storage device, the motor as a drive vehicle. Pure electric vehicle design is one of the cores of the distribution of energy and power [1], Completing this function of the device is pure electric Vehicle controller. Vehicle controller is the pure EV design of the core content of the performance level of the vehicle plays a crucial role. The vehicle controller mainly realizes the functions of normal electric vehicle driving, energy management, CAN network management, condition monitoring, fault diagnosis and processing and so on [2]. The principle is simply speaking pure electric vehicles in different driving conditions, the vehicle controller through the acquisition of accelerator pedal, brake pedal, gear switch, mode switch and other drivers of a series of operating signals[3], combined with the real-time status of the vehicle and the status of the various system components to determine and identify the driver's operational intent, and then according to the established control strategy Control signals are sent to the relevant electrical components to control the vehicle in different states to meet the driver's requirements. The key technology lies in the drive control strategy. Because a good driving control strategy can make the driver have a good driving.

This article focuses on the design and development of a fully electric drive control strategy for pure electric vehicles. From accelerator pedal analog signal acquisition circuit design, signal filtering algorithm to the incremental first-order dynamic low-pass filter of accelerator pedal switch combined with the target output torque filtering algorithm and finally get the best motor torque demand. At the same time, the strategy is tested on the road with more complicated working conditions, which verifies its stability and feasibility. Shown in Figure 1 is the overall flow chart of vehicle ride comfort control strategy.

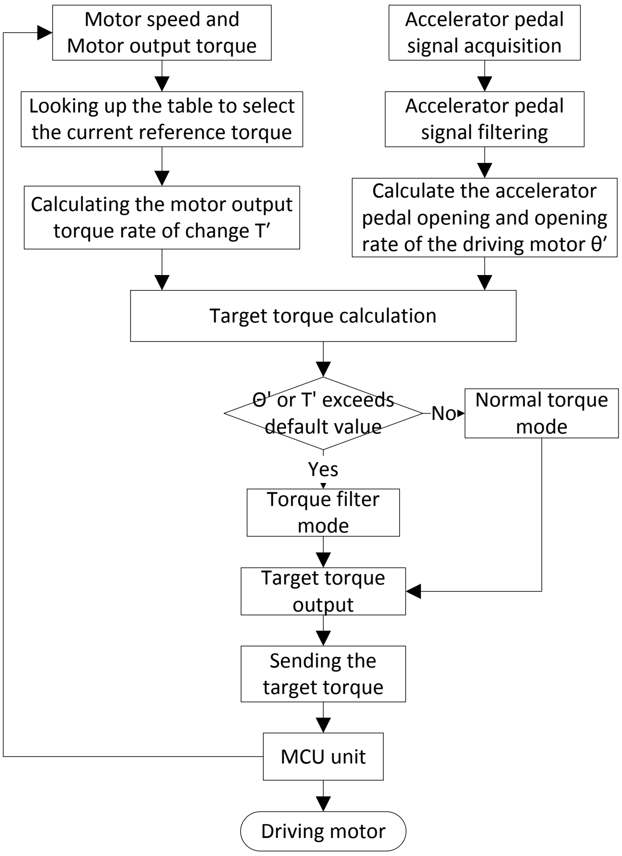

Fig.1 Flowchart of vehicle driving comfort control strategy

2. Accelerator pedal signal acquisition circuit

This analog signal input range is 0 to +5 V, which cannot meet the processing requirements of the system microcontroller 0 to +3.3. V. So the use of partial pressure circuit to collect 0 to 2.5V, and then restore the input analog by software in the paper. Figure 2 shows the analog signal processing circuit. Analog signal mixed with multiple harmonic interferences[4]. First, Writer designs the RC low-pass filter circuit filter out interference components, and then uses the voltage follower, consisting of the op-amp TLVC2372ID, to condition the signal in the paper. CR6 is Schottky diode BAT54S in the picture, which is made up of two reverse parallel Schottky diodes, whose role is to limit the regulated analog signal voltage so that it will not exceed the diode forward voltage drop. Analog signal is processed directly into the master ADC chip module for A / D sampling and conversion.

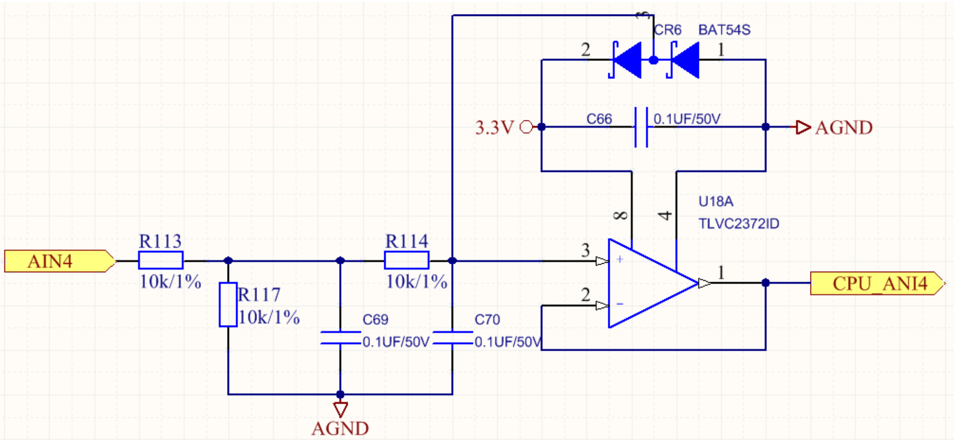

Fig.2 Analog signal processing circuit

3. Accelerator pedal signal processing strategy

The accelerator pedal is important for vehicle driving in the vehicle control. This article designed two acquisition circuits to collect the accelerator pedal signal, of which two analog input circuit signal value is 0 to 5V, and always has twice the relationship. The accelerator pedal signal 1 is used as the main input signal, and the accelerator pedal signal 2 is used as the diagnostic input signal. The theoretical value of the signal 1 is always twice that of the signal 2. Through the real-time diagnosis of two signals to ensure that when the accelerator pedal signal 1 circuit due to various factors leading to failure, the signal can not be read or error, the output of the accelerator pedal signal special treatment. Only when the VCU controller detects that the voltage values of two analog input signals are between 0 and 5 V and the ratio of the two are within twice the small deviation range, it is considered that the accelerator pedal signal input information is valid[5]. Through this design can ensure that ultimately get an effective and reliable accelerator pedal signal to protect the safety of vehicles driving.

3.1 The accelerator pedal signal pulse interference average filter processing

As the system ADC conversion time of about 1us, in the case of external interference through the ADC high-speed data collected cannot be used directly. Using the microcontroller's own DMA automatically and continuously ADC acquisition data is filled into the RAM, after filling a certain amount; by pulse interference average filtering, eliminating occasional pulse interference. Finally, after filtering the signal after diagnosis as the final accelerator pedal signal output. The overall process is shown in Figure 3.

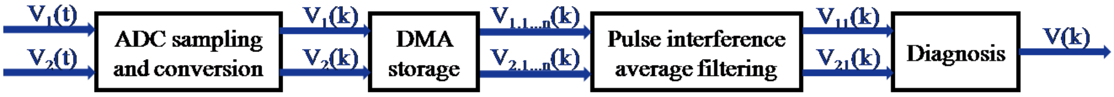

Fig.3 Flowchart of accelerator pedal signal processing

3.2 The Accelerator pedal sensitivity and smoothness of processing

The first stage of the accelerator pedal signal filtering for accidental pulse interference has a certain inhibitory effect. As the vehicle accelerates and decelerates rapidly, the accelerator pedal switch degree will increase sharply and steeply if the accelerator pedal switch degree is not smoothed, which causes the vehicle to vibrate violently during driving; not only affects the driving effect, but will also cause some damage to the motor and the vehicle. In this paper, the first-order low-pass filter with dynamic adjustment of filter coefficients and incremental adjustment algorithm is used to filter the accelerator pedal switch twice to ensure the sensitivity and stability of the accelerator pedal signal. Accelerator pedal switching degree algorithm flow chart shown in Figure 4.

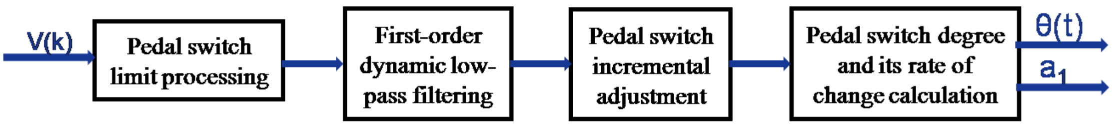

Fig.4 Flowchart accelerator pedal switching degree algorithm

1) Convert the filtered accelerator pedal signal value to a percentage of the pedal switch degree in the range 0 to 100. Accelerator pedal switch limit calculated as

$$\theta_f = \begin{cases} 0 & V(k) < V_{\min} \\ \dfrac{V(k)-V_{\min}}{V_{\max}-V_{\min}} * 100 & V_{\min} \le V(k) \le V_{\max} \\ 100 & V(k) > V_{\max} \end{cases} \tag{1}$$

$V(k)$ is the smoothed accelerator pedal signal value. $V_{\min}$ is the minimum effective voltage value. $V_{\max}$ is the maximum effective voltage value. θ_f is the float accelerator pedal switch.

2) In order to ensure the accuracy of the acceleration pedal switch degree, the accelerator pedal switch degree is rounded to the expression

$$\theta_I = \lfloor(\theta_f + 0.5)\rfloor \tag{2}$$

$\lfloor(\theta_f + 0.5)\rfloor$ is $\theta_f + 0.5$ to round down. θ_I is the accelerated pedal switch for limiter operation.

3) In order to ensure the smoothness and sensitivity of accelerator pedal switch degree filtering, this article uses the dynamic adjustment of first-order low-pass filter coefficient and incremental adjustment of a combination of ways to deal with. Specific programs, the pedal signal value is divided into five degrees: 0 to 20, 20 to 40, 40 to 80, 80 to 90, 90 to 100. After vehicle test calibration as shown in Table 1, the corresponding relationship.

Table 1 Filter coefficients and incremental calibration values

Accelerator pedal switch degree	Filter coefficient	Increment value
~20	0.5	0
20~40	0.7	-0.02
0~80	1	-0.11
80~90	1.3	-0.35
90~100	1.8	-0.8

When the pedal switch value is 0 to 20 and 90 to 100 respectively, the filter coefficient is 0.5 and 1.8, the increment value is 0 and -0.8, which can increase the anti-jamming ability and ensure the stability of low-speed and high-speed operation. The filter coefficient is 0.7 and 1.3, the increment value is -0.02 and -0.35, respectively, which can take into account the stability and sensitivity requirements of the accelerator pedal signal. the filter coefficient to take 1, the increment value of -0.11, when the pedal signal value is between 40 and 80, 80 opening, to increase the response speed to ensure that the acceleration performance requirements.

The final output of the accelerator pedal opening coefficient of expression is:

$$\theta = \frac{k\theta_I}{100} + \Delta\theta \tag{3}$$

θ is the Accelerator pedal opening coefficient that is the final output of the accelerator pedal. k is the for the filter coefficient. θ_I is the accelerator pedal switch speed limit. $\Delta\theta$ is the Incremental adjustment for acceleration switch.

4) In this paper, the design of acceleration torque output control also incorporates the accelerator pedal change rate of change, it can more accurately express the driver's intention to accelerate. Accelerator switch rate of change of expression is

$$\theta' = \frac{\theta_e - \theta_s}{t_e - t_s} * 100\% \tag{4}$$

θ' is the accelerate the rate of change of the pedal switch. θ_e is the current accelerator pedal switch degrees. θ_s is the accelerate the front accelerator pedal switch. t_e is the after the acceleration time point. t_s is the acceleration time point.

4. Output torque control strategy

Torque output strategy refers to the VCU real-time acquisition CAN bus motor output torque rate of change and motor speed, combined with accelerator pedal opening and rate of change, and then analyze the driver's intentions. VCU torque output control strategy includes normal mode and torque filter mode. Normal mode calculatess the VCU target output torque when the output torque change rate of the motor or the change rate of the accelerator pedal signal does not exceed a preset value, and search for the peak torque limit MAP table based on the current motor speed in combination with the accelerator pedal opening degree. Torque filter mode: When the rate of change of the output torque of the motor or the change rate of the accelerator pedal exceeds a certain preset value, the VCU judges that the vehicle is in a fast acceleration or rapid deceleration condition and controls the output torque by the torque filtering control method. Through the above method to improve the smoothness of the vehicle torque output, as far as possible to avoid torsion vibration of the main drive shaft, thereby enhancing the ride comfort and vehicle driving. Figure 5 shows the output torque control strategy flow chart.

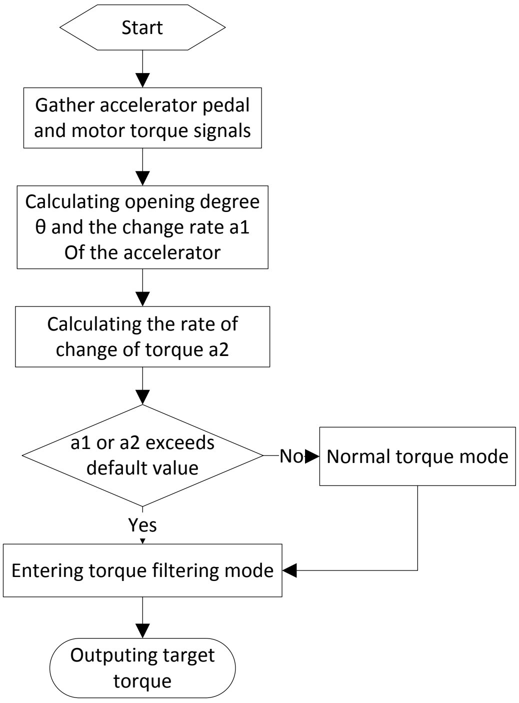

Fig.5 Flowchart of output torque control strategy

4.1 Output torque normal mode control

According to the mechanical characteristics of the motor shown in Figure 6 and the basic parameters of the motor, the motor speed is divided into three levels, 0 to 3000, 3000 to 7000, 7000 to 7300. The reference torque at different motor speeds is a function of the target output torque and accelerator pedal opening based on the dynamic demand and real road test.

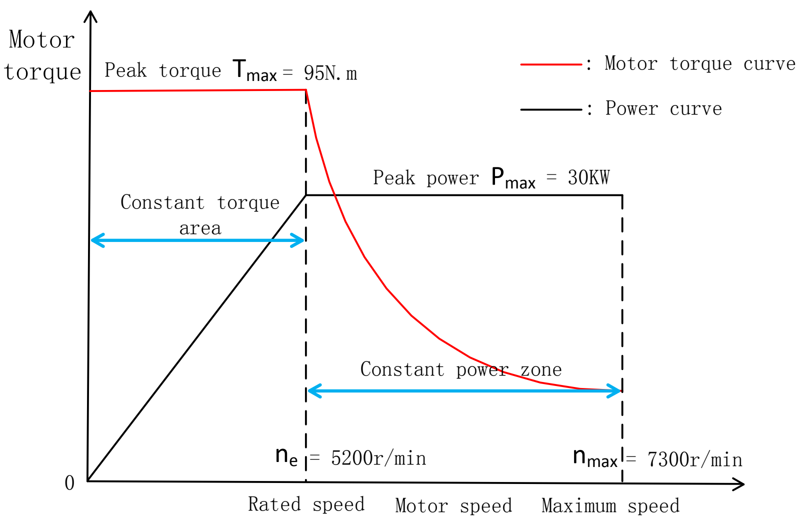

Fig.6 Motor mechanical properties and basic parameters curve

1) When the motor speed is 0 to 3000 that is, low-speed acceleration driving torque demand characteristics[6], combined with the above roadmap and real road test, the reference torque calibration as shown in the following table:

Table 2 Reference torque calibration

Motor speed	Demand torque	Unit
0~500	95	N.m
500~750	94.3	N.m
750~1250	93.8	N.m
1250~1750	92.9	N.m
1750~2250	92	N.m
2250~3000	91.2	N.m

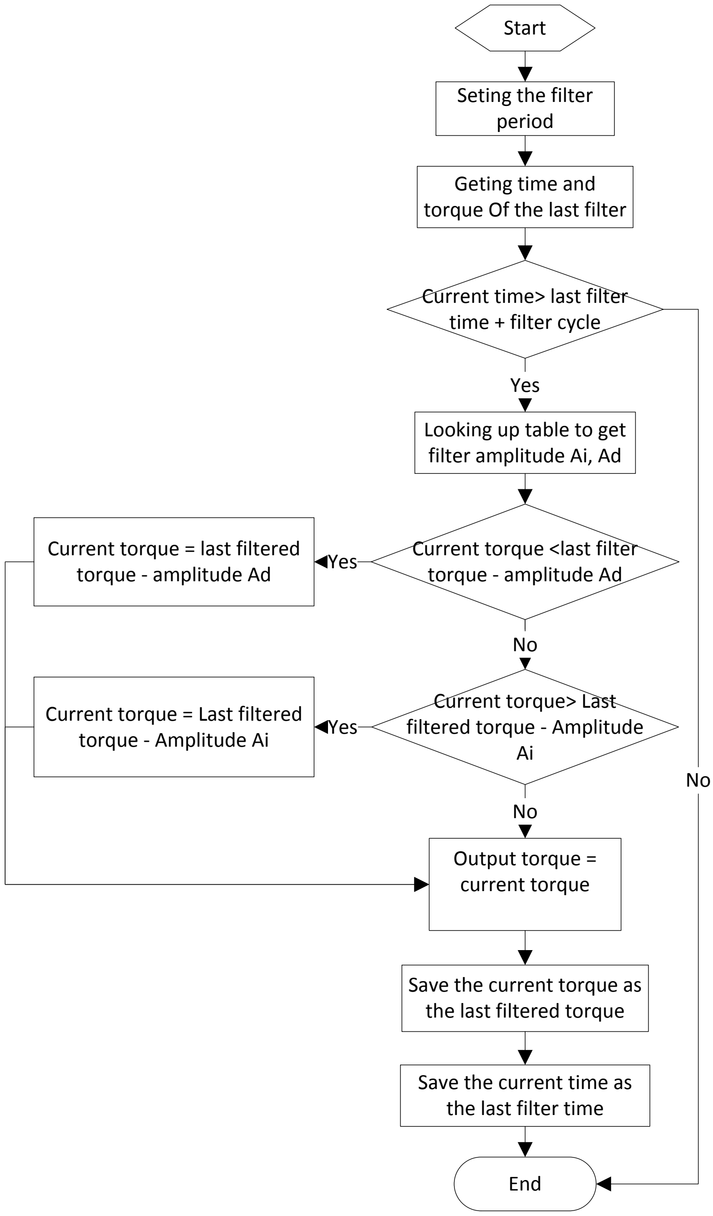

Fig.7 Flowchart output torque filter mode

2) When the motor speed is greater than 3000, which means the torque demand is small when the motor speed is constant and the reference torque expression is

$$T_p = \begin{cases} \dfrac{9550*T_c}{V_m} & 3000 < V_m \le 7000 \\ \dfrac{4775*T_c}{V_m} & V_m > 7000 \end{cases} \tag{5}$$

T_p as the reference torque. T_c as torque constant for motor parameters. V_m as the motor speed.

Under the control of the output torque normal mode, according to the existing accelerator pedal opening degree coefficient and the motor output torque calculation relationship, combined with real road test results; the target output torque and accelerator pedal opening coefficient as a function of the approximate linear The relational expression is

$$T_o = \lfloor \theta * T_p + 0.5 \rfloor \tag{6}$$

T_o as the output torque for VCU target.

4.2 Output torque filtering mode control

When the vehicle is accelerating or decelerating, in order to improve the ride comfort and comfort of the vehicle, this paper uses the look-up table to filter the output torque. Find the amplitude filter limit table based on the current electronically controlled output torque to obtain the rising limit and the falling limit of the amplitude filter. When the torque changes too fast, the value of periodically adjusting the output torque to ensure that the torque is a slow decline rather than a sharp decline, rising slowly rather than sudden. Figure 8 is a flowchart of the output torque filtering mode.

5. ehicle Ride Drive Control Strategy Test Verification

The vehicle ride comfort control strategy is restored to the VCU software to complete the development and download to the vehicle controller based on the STM32F4 hardware platform, while the assembly to a pure electric vehicle designated body position, the use of vehicle OBD diagnostic port and CANoe tool through CANoe PC software real-time monitoring and record vehicle CAN network information.

5.1 Accelerator pedal signal processing algorithm validation

Microcontroller through the ADC module in the acquisition of the external analog signal, due to other external factors, there will be some hardware cannot be filtered out interference signal, resulting in the acquisition of accelerator pedal analog pulse interference signal; as the accelerator pedal signal is Very important control of the car driving signal, the accuracy is very high. In this paper, the pulse interference average filter to ensure the accuracy of the acquisition signal, according to the real car test and verification, through the signal filtering accuracy of 0.01v. Figure 8is an accelerator pedal signal pulse interference average filtering before and after the comparison of the effect is through the VCU will collect the accelerator pedal signal processing signal and the original signal through the CANOE tool upload to the host computer software screenshot. From the figure can be drawn that the average pulse interference filtering of external interference signals have a good filtering effect.

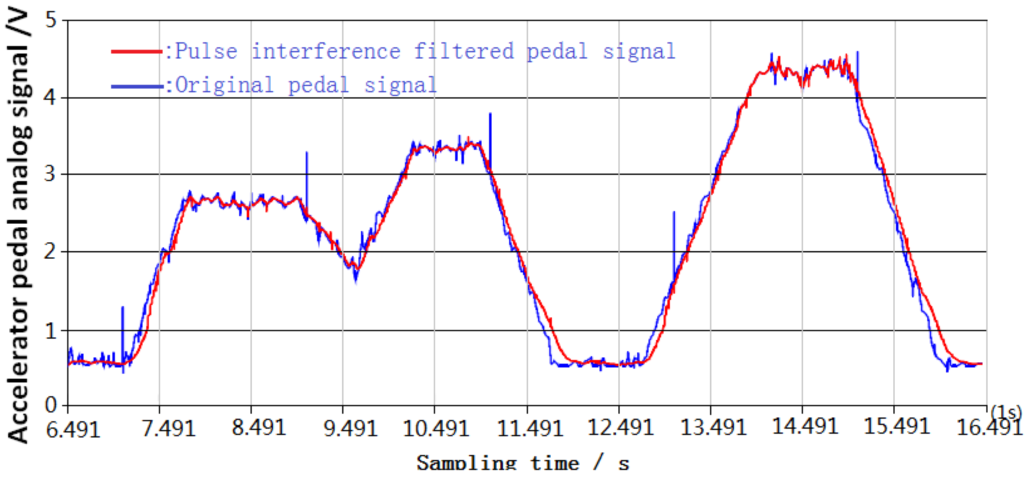

Fig.8Accelerator pedal pulse interference average filter comparison chart

In order to ensure the smoothness of the car driving process, this paper through the two-stage combination of the way the car in the rapid acceleration and deceleration process does not appear any jitter phenomenon, giving the driver a comfortable driving feeling. Figure 9 below is the first level of processing, and the use of dynamic adjustment of the first-order low-pass filter coefficient and incremental adjustment of a combination of accelerator pedal signal processing. It can be seen from the figure that the processed signal is more stable than the untreated pedal signal, while still maintaining the sensitivity.

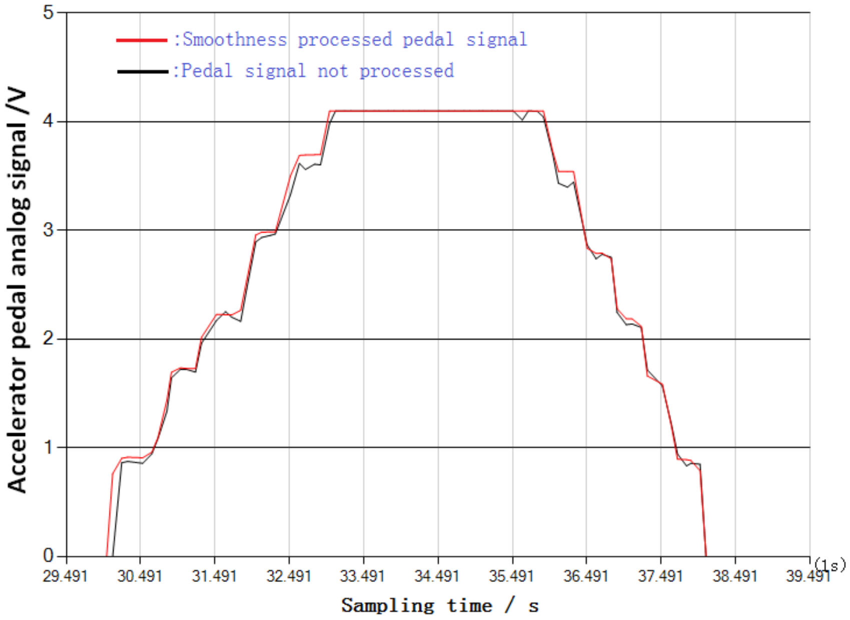

Fig.9 Comparison chart of accelerator pedal signal smoothing and smoothing

Figure 10 is the dynamic adjustment of the first-order low-pass filter and incremental adjustment of a combination of ways to deal with the accelerator pedal signal into a switching factor.

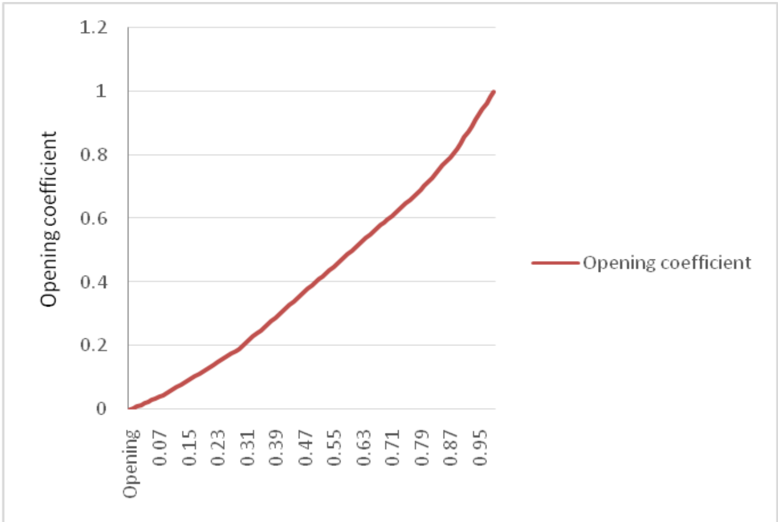

Fig.10 Accelerator pedal opening coefficient

5.2 Torque signal processing algorithm validation

Figure 11 shows the linear relationship between pedal opening an actual torque of a pure electric vehicle from uniform acceleration to maximum speed. The experimental data show that under the normal torque-normal operation mode of a vehicle running at a uniform speed or a uniform acceleration, according to the actual motor characteristic parameters The calibrated reference torque parameter combined with the pedal opening degree, the actual output torque calculated through the linear relationship accords with the mechanical characteristic curve of the motor, and the pure electric vehicle has no obvious jitter during the driving.

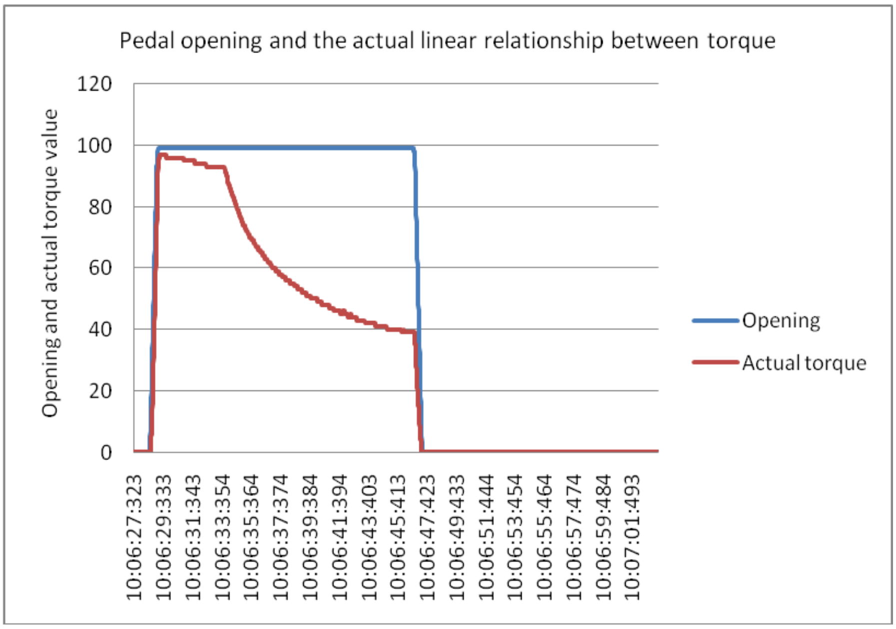

Fig.11 Linearity between pedal opening and actual torque

If the real car road test for a long time the pure electric vehicle rapid acceleration and deceleration, will give testers some unacceptability and danger. Therefore, this article for the rapid acceleration and deceleration test method is through the vehicle lifts the entire vehicle rack up; and then rapid acceleration and rapid acceleration operation. Figure 13 shows the relationship between the pedal opening degree and the actual torque when the torque is not in the filter mode. It can be seen from the figure that when the pedal is rapidly accelerating or decelerating, the actual output torque fluctuates very large, which will give the whole Very large car jitter, shorten the life of the car, the driver is very uncomfortable driving experience and feeling.

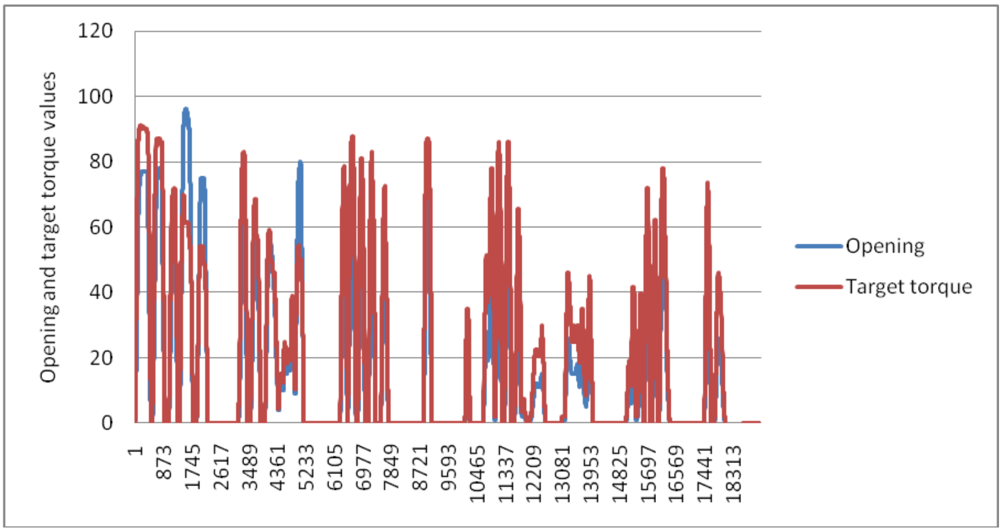

Fig.12 Unfiltered pedal opening and actual torque diagram

Figure 13 shows the relationship between the pedal opening and the actual torque after the second-stage filtering, that is, the torque filtering mode, is used for the output torque control. It can be seen from the figure that when te vehicle is accelerating or decelerating rapidly, the output torque enters the filter control mode and adjusts the value of the output torque periodically so as to effectively ensure that the torque will slowly decline instead of steep and rise slowly Not sudden. Improve vehicle ride comfort and comfort, but also effectively extend the life of the car.

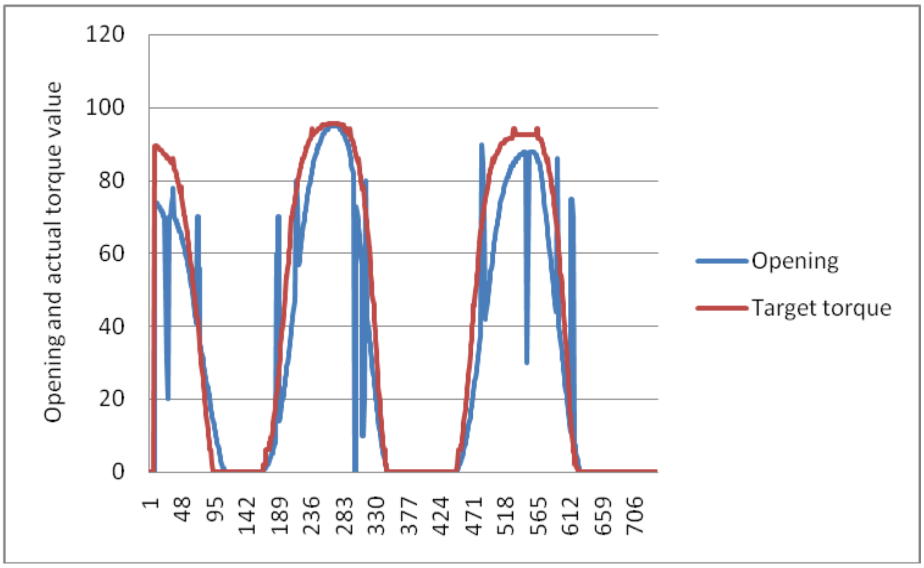

Fig.13 Filtered pedal opening and actual torque diagram

6. Conclusion

This paper first analyzes the analog signal hardware acquisition circuit board, through the RC low-pass filter circuit can filter out some interference components; but some interference signals need software filtering. In the following, the paper mainly researchers on the algorithm of pedal signal software filtering and smoothing. Combined with the data from real road test, the pulse interference average filter used in this paper can well filter out the pulse interference and ensure the accuracy of pedal signal acquisition. Secondly, we use the first-order low-pass filter with dynamic adjustment of filter coefficients and incremental adjustment algorithm to filter accelerator pedal switch twice. From the experimental data, it can be concluded that this filter method can effectively ensure the sensitivity of accelerator pedal signal and Stationary. Finally, according to the motor mechanical characteristics combined with accelerator pedal opening and torque rate of change, the driver's intention is analyzed and the VCU torque output is controlled by the normal linear model and torque filter mode. According to the actual test results, the torque control strategy can effectively improve the ride comfort of the vehicle and improve the smoothness and comfort of the vehicle. In this paper, the pedal signal acquisition circuit and software filtering can be applied to different models of VCU program, but the torque control strategy because it must be based on the mechanical properties of each motor, so applied to different models of VCU, must be based on its mechanical motor Characteristics of the appropriate changes and adjustments.

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