Research on Vehicle Driving Force control Based on Real-time Operating system

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***Abstract*-Based on the 32-bits Embedded Microprocessor MPC565,a target controller of the driving force control system was developed for a light 4WD vehicle which includes the electronic-controlled diesel engine and TC(Torque Converter)+AMT(Automatic Mechanical Transmission). Also, the control algorithm is developed based on the Real-time Operating System (RTOS). The hardware-in-the-loop tests were carried out in the test bench where the vehicle was started and accelerated on the low-µ road and the split-µ road respectively. The test results show that the driving force control system can work reliably and avoid the excessive spin of driving wheels and obviously improve the drivability.**

Keywords-Vehicle driving force control, Control algorithm, RTOS, Hardware-in-the-loop

I. INTRODUCTION

With the development of automotive technology, higher requirements for vehicle performance have been put forward. It makes the control systems in the car more and more complex. At the same time, the requirements for the control systems including real-time, stability, control accuracy and communication reliability and other respects increased [1]. It has become the development trends for the car industry to use high-performance 32s-bit microprocessor and RTOS based on OSEK / VDX standard for development of complex automotive electronic control systems [2,3].Vehicle driving force control system always monitors the states of vehicle driving wheels and can avoid the over slip of the driving wheels by redistributing the driving force with the coordinated control between electronic-controlled engine and TC+AMT system as well as brake control of the driving wheels. Therefore, the vehicle driving force control system can not only improve the ride comfort and make the vehicle easier to operate, but also make full use of the ground cohension to improve the driving efficiency and enhance the acceleration and handling stability of the vehicle.

In this paper, the driving force control system for a 4WD off-road vihicle is designed including the target controller and the control algrithom based on the multitask operating system. At last, the control effect of the driving force control system is verified through the hardware-in-the-loop(HIL) test.

II. CONFIGURATION OF VEHICLE DRIVING FORCE CONTROL SYSTEM

As is shown in Figure 1, vehicle driving force control system is a distributed electronic control system that contains a few electronic control units based on vehicle network. It mainly includes the Traction Control System (TCS), engine throttle control system and TC+AMT system which exchange data by CAN bus. Communication protocol of CAN bus reference SAE J1939E Standards and CAN hardware layer follows the CAN2.0B protocol.

TCS system collects the signals such as the vehicle acceleration, wheel speeds and the throttle position signal by bus when the vehicle is running, then judges the slipping states of the driving wheels, and makes the traction distributed to the driving wheels to match the road adhesion by changing the output torque of the engine and the brake pressure of the driving wheels. At the same time TCS system receives the gear state message on the bus from TC+AMT ECU and sends gear intervention signals to TC+AMT ECU by the bus for coordinated control between TCS and TC+AMT;

Engine throttle control system directly gathers throttle pedal position signal *Kd* and receives throttle adjustment information from TCS and TC+AMT by CAN bus. Then through D/A converter it outputs the throttle control signal to the engine ECU to regulate the engine output torque.

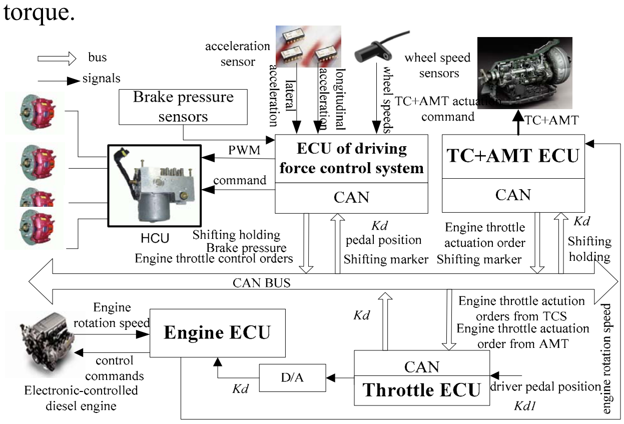

Figure 1. Configuration of vehicle driving force control system

By CAN bus, TC + AMT ECU receives throttle pedal position signal *Kd* from the throttle ECU, engine rotation speed signal from engine ECU and the gear intervention signals from TCS, then outputs the control orders to the TC+AMT actuators according to the shafting algorithm of automatic transmission.

III. ECU OF THE DRIVING FORCE CONTROL SYSTEM

In order to meet the requirements of reliability, rapidity, precision and real-time for the complex control system, MPC565, a Motorola 32-bit embedded microprocessor, was selected as the CPU of the ECU with the high processing speed, large capacity of data storage, abundant on-chip resources, low operating voltage and power consumption.

ECU hardware mainly included the supply power management module, clock circuit, reset circuit and external memory expander circuit. Power management module mainly managed the power output in order to guarantee a stable voltage for ECU. The signal acquisition module preprocessed the input signals such as pulse, analog and digital signals which were detected and captured by MDASM, QAD64E and I / O ports of the microprocessor.

The output module was designed to amplify the output control signals of ECU in order to drive the solenoid valves and pump motor of the hydraulic control unit(HCU). Based on the CAN bus, communication module was developed to finish the communication between the engine throttle ECU, engine ECU, TCS ECU,TC+AMT ECU and the host controller to share all the system information and exchange data online.

IV. DRIVING FORCE CONTROL SYSTEM SOFTWARE

A. *Driving force control algorithm*

Coordinated control was used in the driving force control system with the engine throttle control, driving wheels brake control and gear intervention control of AMT. At the same time, PID control method was used for the engine throttle control, the logic threshold control method was used for driving wheels brake control [4]. The shafting actuation order was decided by both the AMT ECU and TCS ECU for the avoidance of the control conflict because the engine throttle maybe is controlled at the same time by both TCS and AMT during the work period [5]. And shifting operation was performed by AMT ECU. The integrated control process is shown in Figure 2.

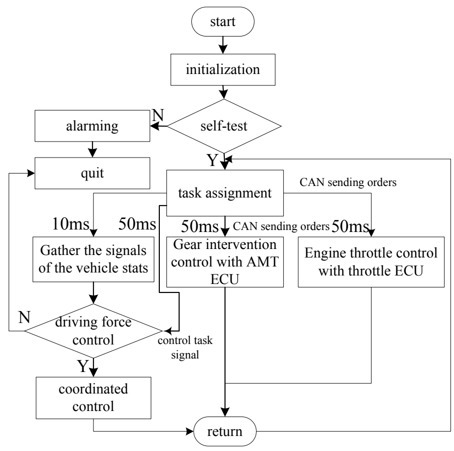

Figure 2. Flow of the integrated control process

In Figure 2, firstly the system initialization was done for ECU RAM, FLASH, and AD, DA, CAN, PWM module of system to ensure that the program can run normally. Then the system performed the self-test for the fault detection, and system fault lights start to alarm and the emergency measures will be activated to quit system control if some faults are found. Or according to the task configuration of real time operating system, tasks will be performed as follows: the gather of sensor signals, wheel speeds calculation, reference speed estimation based on the wheel speeds and the acceleration value, wheel slip calculation and the target wheel speeds, which determined whether the actuators are activated to work. If so, CPU will call the throttle control and brake control subroutines; else exit the control cycle. Meanwhile the CAN communication always is kept among TCS controller, AMT controller and throttle controller.

B. *Design of real-time multi-task system*

Vehicle driving force control system is a real-time multi-task system including the scheduling tasks, control tasks and monitoring tasks.

Scheduling tasks include the scanning of the input signals, the clearness of the watchdog counter, the sending of the control orders according to the control algorithm and the control commands to the CAN bus, etc.. According to the different real-time requirements, each task was assigned for specific priority.For example, the scanning task was activated every 10ms by the timer, and the other schedule tasks wer activated every 50ms (shown in Figure 2); Control tasks, activated by the actuation commands, processed the input data and called the corresponding subroutines by the control algorithm. Monitoring tasks finished the communication with the host computer and run the monitoring program to monitor the key variables of controller.

Each task was assigned to a specific priority level. Scheduling task was to the highest priority level 1, followed by control task which is 2, and priority level of monitoring task is 3. Scheduling task was performed regularly with the designed period, and sent control task signals to schedule and switch tasks.

V. Hardware in the Loop Test and Result Analysis

For the 4 × 4 light off-road vehicle, German dSPACE system based on MATLAB was chosen as the development and testing platform of the hardware in the loop system. And the hardware in the loop tests based on the target controller were performed including starting and accelerating straight on low-μ road and split-μ road respectively for testing the control effect.

Meaning of the curves in Figure 3-6 is: 1,2,3,4 - speed of the left front wheel, the right front wheel, the left rear wheel, the right rear wheel; 5 – the vehicle speed, 6 - AMT gear; 7 – the accelerator pedal position by the driver; 8 - the accelerator pedal position after control; 9,10,11,12 - brake cylinder pressure of the left front wheel, the right front wheel, the left rear wheel, the right rear wheel.

A. HIL test on low-μ road

On the HIL bench, the vehicle was tested to start and accelerate straight on low-μ road where the road adhesion coefficient is 0.1. The test results without control are shown in Figure 3.

As can be seen from the curves in Figure 3 that the driver stepped the accelerator pedal to 100% at the beginning and the driving wheel speeds surpassed the vehicle speed quickly with excessive slip because of the relatively poor road adhesion. At the same time, AMT gear continuously increased to 3 position only at 4s because the gear was decided by the wheel speeds and driver accelerator pedal position according to the AMT shifting control algorithm. As a result, the vehicle speed was only 17.8km/h when simulation time was 8s.

Test results with control are shown in Figure 4. When the excessive slip of the driving wheels was detected, the controller began to work by adjusting the engine throttle quickly to control the engine output torque. At the same time, AMT gear was always kept at 1 positon about 4s by the intervention control of TCS to enhance the driving force. Therefore, the excessive slip of the driving wheels was obviously improved, and the vehicle speed was 19.1km/h when simulation time was 8s.

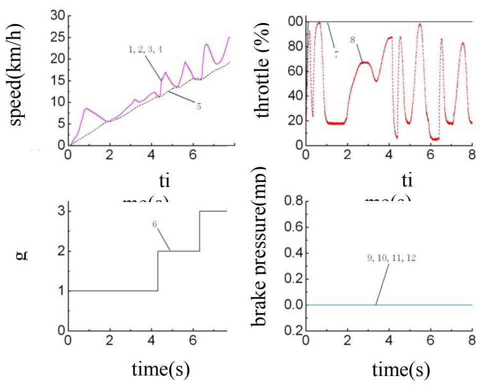

Figure 3. Test curves on low-μ road without control

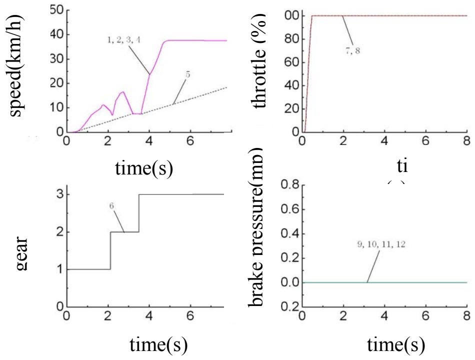

Figure 4 .Test curves on low-μ road with control

B. HIL test on split-μ road

The vehicle was tested to start and accelerate straight on split-μ road where the left and right wheels were on road with adhesion coefficient 0.6 and 0.1 respectively. The test results without control are shown in Figure 5.

The driver stepped the accelerator pedal to 100% at the beginning and the right driving wheel began to slip because of the relatively low road adhesion.

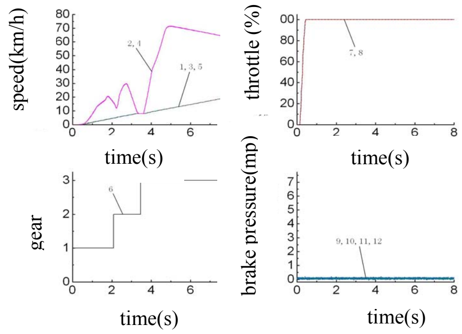

Figure 5. Test curves on split-μ road without control

Similarly, AMT gear continuously increased to 3 position about at 4s without AMT shifting intervention control. As a result, the vehicle speed was only 19.8km/h when simulation time was 8s. Test results with control are shown in Figure 6. When the excessive slip of the right driving wheels was detected, the controller began to work with the coordinated control by adjusting the engine throttle, the brake pressure control and the AMT gear intervention control. Therefore, the excessive slip of the driving wheels was obviously improved, and the vehicle speed was 26.5km/h when simulation time was 8s. With comparison, the acceleration performance was improved 34%.

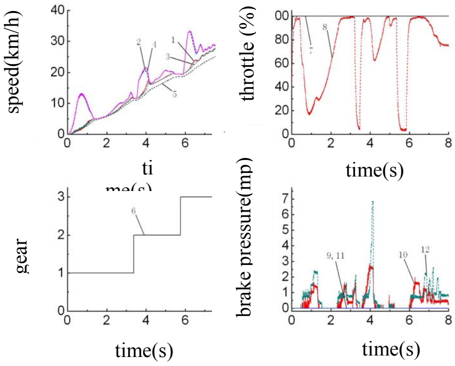

Figure 6. Test curves on split-μ road with control

VI. SUMMARIES

For vehicle driving force control system, the ECU based on the embedded 32-bits microprocessor was designed and the control algorithm was developped based on the corordinated control. At last, HIL tests were done on the typical road for the validation of the control effect and the test results show that the driving force control system can obviously improve the driving performance.

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