EVS25

Shenzhen, China, Nov 5-9, 2010

Research and Development of Wheel-motor Fuel Cell Electric Vehicle

Xiong Yun[1,2], Han-mo Zhao[1], Ting-ting Yin[2] and Zhang Tong[1,2]

1College of Automotive, Tongji University Shanghai 201805, China

2Shanghai Fuel Cell Vehicle Powertrain Co., LtdShanghai 201805, China

Email:xiongyun@fcv-sh.com

Abstract

The article gives an illustration about low speed wheel motor hybrid vehicle(LWP), firstly, introduces the structure of fuel cell vehicle and function of components; secondly, presents vehicle control policy, thirstily, takes an emulation about the power performance of LWP; lastly, experiment checking the simulation result, proofs the power performance of fuel cell vehicle.

Keywords：Fuel cell vehicle; components; control system

1. Introduction

Developing fuel cell vehicle is an effective way to air pollution management. Fuel-cell vehicles working principle is to use hydrogen and oxygen to produce electricity, and the chemical reaction with electric drive vehicle, and the previous exercise on gasoline or diesel vehicles powered) compared with the energy efficiency and pollution emission, and many other advantages, is expected to power cars in the 21st century. But a fuel-cell car the biggest advantage is cleans, no pollution, which is the only waste water discharge. Therefore, they urged their government to formulate the corresponding policies. Currently, the United States, Europe and Japan's car manufacturers speed up to develop fuel-cell technology, maybe3-4 years, fuel-cell cars are expected to reach batch production stage, and put in the market. Although the new energy vehicles now seemed far away from the Chinese people, but as a strategic layout of automobile industry, the Chinese government has already developed new energy vehicles such as electric development direction in the future.

2. Fuel Cells Vehicle Structure and Theory

The main source of Fuel cell vehicle is battery, and Fuel cells for auxiliary power supply, fuel cell in parallel with the motive battery by DCDC dc converter, supplying motor and other components to drive vehicle. According to the classification of different motor, motor is

divided into focus motor and wheel motors, the forth drive vehicle by a focus motor, the later drive by four-wheel motors. The 120V/12V voltage dc converter complements for12V battery. Traction battery can external connect 220V charger. This article is low-speed wheel motor hybrid vehicle as an example to introduce the fuel cell vehicle

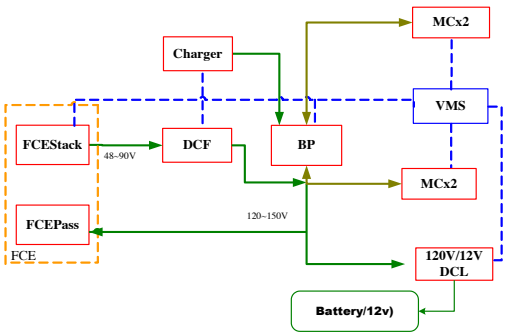


Figure 1: Fuel cells vehicle structure diagram

3. Introductions of Fuel Cell Vehicle Components

3.1 Fuel Cell System

FC is a electrochemical reaction directly convert into electricity device by Fuel (hydrogen) and antioxidant (oxygen) chemical energy, the process does not involve burning, The mechanical consumption, Energy conversion reach up to 80%, the product is Electricity, heat and water vapor; and FC run steady, No vibration and noise, therefore, it is Considered the 21st century green energy. The following is fuel cell system working principle.

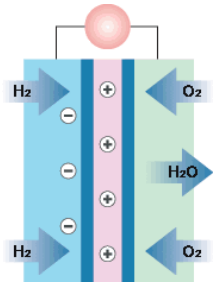


Figure 2: fuel cell system working principle

FC technology applications of vehicles has brought the revolutionary breakthrough for automobile industry, at the same time improve its own development.

In fact, people more consider FCEV, which is different from traditional car, the dynamic comes from FC, is not internal-combustion engine, could reduce fuel consume, generate less discharge of pollutants. When use hydrogen as fuel, it will realize the "zero emission car." As a result, it is more suitable for people Economic and environmental protection concept. Besides, when energy exhaust, FCEV is not likely traditional can which battery need more time to charge, just added fuel to continue work, it is convenient to car drivers.

The table 1is introduced fuel cell system performance by wheel-motor fuel cell electric vehicle.

Table 1: fuel cell system performance

Power	High speed	Voltage
0.8/2KW	580 rpm	120V

The mainly development of FCEV has two kinds: Pure fuel-cell cars and battery-fuel cell hybrid vehicle. Pure fuel-cell cars adopt The stack with high power FC, make sure to provide force of start and Instantaneous speed if has no reserve battery; battery-fuel cell hybrid vehicle mainly use battery as the principle power, small power of fuel cell to be proceed device.

3.2 Drive System

Motor drive and control system is the device of Electrical and mechanical energy in electrical vehicle. In electric drive mode, electricity which comes from Fuel cell engine and battery

power is convert to Mechanical power drive and overcome the resistance; In regenerative braking mode, kinetic energy converts to electrical energy stored in the battery power. The table 2 is introduced wheel-motor performance by wheel-motor fuel cell electric vehicle

Table 2: wheel-motor performance

Fuel Cell System performance	performance
Range of current（A）	0～120A
Range of voltage （V）	45～100v
Output total power（W）	0～6000
Auxiliary power consumption（W）	0～1000
Net output power	0～5000
system efficiency （%）	>80%

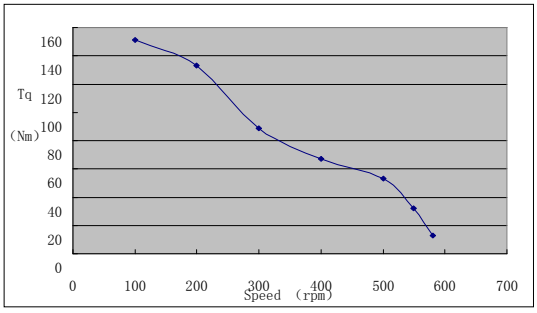


Figure 3: 800w Wheel motor mechanical characteristics curve

The electric motor controller power on, and build communication relationship with vehicle system, report parameters. The normal state after closing high-voltage power system, controller receives VMS order. Motor goes into working state, after receive the Torque signals from VMS, Output torque. Motor rotates normal. When the motor receive negative Torque signals, the motor into the regenerative braking condition, this moment Motor as a generator, transmit power to battery.

3.3 Storage Battery Management System

Battery power is power source, the effect contain supplying power electricity in Electric mode, under Fuel cells mixed mode, Battery power and Fuel cells Provide power supply or recycled fuel cells extra energy together, and In regenerative braking feedback absorption braking energy.

The table 3 is introduced battery parameters by wheel-motor fuel cell electric vehicle.

Table 3: battery parameters

Battery	capacity	voltage class
LiFePO4 battery	45AH	128V

According to batteries, the main control VMS work is sending enables and relay closure. When BMS receiving can signal from VMS, BMS start doing relay closure. First Process is closed in battery charging relay gets charging process 100 European resistances protection in bus bar on the string. When the capacitance battery voltage is 90% percent for total voltage, main relay closure of, charge relay gets off. Relay closure action is finished

BMS has a switch for charger. BMS judge For battery voltage, total voltage and temperature. If the condition allows, BMS sent the rechargeable signals to charger (including the relative dynamic voltage and current of the constant charge). When charging, charger adopts the method of constant flow pressure charge. When the total voltage reached the value, the charger should convert into constant pressure charging. When charging current smaller than 2A, BMS will send charging close signals. In this process, if the voltage or

temperature abnormality, BMS can send emergency charging closed signal.

3.4 Charger System

Electric vehicle with battery charger adopts high frequency switching power supply mode. Input voltage dc, rectify to ac, then High-frequency bridge switch circuit rectify to the requirements by-lowing battery.

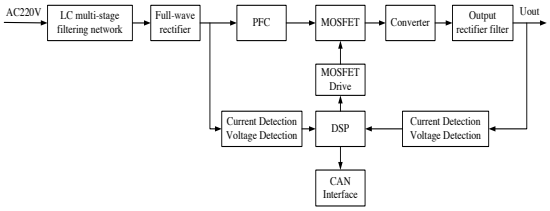


Figure 4: The Basic Structure of the On-board Charger

External 220VAC, 220VAC shift 12V first work, Provide control power, run program. Input voltage side at advance charging status, while wait for the CAN corresponding control signal, the CAN bus voltage and voltage current set signal. When that can signal is given and advance charging complete the relay closure, then according to the voltage set value (or default) began to work. Charging process is divided into constant-current, constant pressure, trickle flow three stages, when the test output data reach set value and the output current less than set value stop work.

The table 4 is introduced charger parameters by wheel-motor fuel cell electric vehicle.

Table 4: charger parameters

Output power rating	1800W
Output rated working efficiency	80%
Input voltage	220VAC±10%
input current	0～10AC
Output voltage	110～150V
Current output	0～12A

3.5 DCDC

DC/DC converter, namely DCDC converter, adopt closed-loop control output current for fuel cells to achieve the effective control of the instantaneous power engine, assure to adjusting power battery charged state.

The table 5 is introduced DC/DC parameters by wheel-motor fuel cell electric vehicle.

Table 5: DC/DC parameters

Output power rating	6KW
Output overload ability	30%
Output rated working efficiency	90%
Input voltage	45～120V
input current	0～150A
Output voltage	140V±10%
Current output	0～40A

3.6 DCL

DCL is described as vehicle-mounted Low voltage dc 12V convertor, it Will step-down 120V high-pressure around for 12V to the battery charging. The working process for the DCL controller sequence electric program, DCL waiting to corresponding CAN command (output signal) start work, report the corresponding working state.

The table 6 is introduced DCL parameters by wheel-motor fuel cell electric vehicle.

Table 6: DCL parameters

Output power rating	0~1500W
Output overload ability	10%
Output rated working efficiency	85%
Input voltage	110V~150V
input current	0~14A
Output voltage	13.5V
Current output	0~120A

3.7 Hydrogen Management System

Hydrogen management system using the XC164 chip CAN controller，By receiving VMS orders to control the hydrogen electromagnetic valve on-off. At the same time detect hydrogen pressure, temperature, leak signal and sent to VMS via the can bus.

Control hydrogen magnetic valve, by collecting hydrogen pressure, temperature, hydrogen leak, etc, to realize the hydrogen fuel cell system management.

The table 7 is introduced hydrogen management system by wheel-motor fuel cell electric vehicle.

Table 7: hydrogen management system parameters

rated voltage	12VDC
Working voltage	10-16V
Working temperature	-25℃～65℃
Storage temperature	-40℃～75℃

3.8 Display

Instruments used to display the running state of power system, which is the main way for drivers to understand condition of vehicle。 Display instrument including instrument which behind the steering wheel and the central passageway display DVD on the big screen. By CAN and signal wire, display instrument show the key components parameters and status of power system.

Figure 5: Fuel-cell car DVD showed interface

4. Automobile Control Systems

The basic principle of power train control according to the input of instructions of the driver，coordinate The main components of power train to work together，adjusting speed and direction of Each link of energy conversion，On the premise of economic indicators，Realize the drivers expectation of dynamic performance. The reliable of control function realization mainly depends on the following aspects of specific control strategy implementation.

4.1 Feedback Braking Control Strategy

Feedback braking operation is controlled by accelerating pedal controlling motor torque to implement. Through The motor power feedback function vehicle Kinetic energy convert into electrical energy stored to the energy components in the decelerate process,

In order to realize the energy recovery, achieve to save energy.

$$\eta_2 = \frac{E_A}{E_T - E_F} \quad (1)$$

In the equation: E_A is the actual feedback energy; E_T is the theoretical feedback energy; E_F is the energy consumed because of resistance.

To be EV and HEV of Relations between Electric braking torque and mechanical friction slices braking torque All Parallel hybrid electric vehicle have a simple structure and control strategy. In a typical urban condition, for most of the braking energy recovery is efficient. Only in the front wheel has brake recovery. The front braking torque size has relation with Friction force generated by braking force of electric braking system and Mechanical braking system [3].

4.2 Load Balancing Strategy

Mixed electricity fuel-cell cars has a variety of power supply device, the car transient load how to reasonable Allocate to the different energy device, is usually said load equilibrium strategies. Practical load balancing suggested that is based on thinking over the influence of Power train parts characteristics, fuel economy [5].

$$I_{dcf} = I_{mc} + I_b \quad (2)$$

Because DC/DC converter adopt constant flow control, Power battery instantaneous power completely depend on the difference between the need of DC power by motor controller and DC/DC converter output power. The motor controller basic outputs trend is changed by the manipulation of driver instruction, as a result, load equilibrium strategies in power train system realize by Adjust DC/DC converter output power. The article Using regulate the DCDC output current to control Power battery SOC Always keep in a certain range, to maintain the demand of vehicles normal operation [4].

4.3 Fault Treatment Control System

Like traditional vehicles diagnosis and processing, the main objectives of fuel cell vehicle fault diagnosis and processing are: To ensure traffic safety, reliability and stability. In order to achieve the goal, fault processing base on classification principle is used in fuel cell vehicle. Overall processing strategies are as Table 8.

Table 8: Fault description and processing

Fault level	Fault description	Fault processing
Level 1	Dangerous fault	Emergency shutdown
Level 2	Severe fault	Request shutdown
Level 3	General fault	Limit the power
Level 4	Slight fault	Just Record

5. The Theory Simulation

Vehicle calculations

Table9: the fuel cell vehicle parameters

full load quality（Kg）	2020
half load quality（Kg）	1580
Wheel radius R（m）	0.269
Windward acreage A（m2）	2.8
The wind resistance coefficient C_D	0.35
Rolling resistance coefficient f	0.018
Mechanical efficiency	1
Motor + controller combined efficiency	0.8
ratio	1

5.1 Highest Speed

Simulation curve

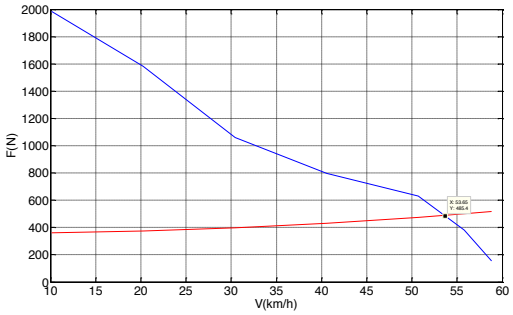


Figure 6: driving force and resistance curve

The point of intersection is maximum speed: 53.65 $^{km}/_{h}$.

5.2 Climbing Capacity

$$\partial = \arcsin\frac{F_t - F_f - F_W}{G} \quad (3)$$

$$F_t = \frac{T_{tq} i_g i_0 \delta}{R} \text{ (Driving force)} \quad (4)$$

$$F_f = fG \text{(Rolling resistance)} \quad (5)$$

$$F_W = \frac{C_D A u^2}{21.15} \text{(Atoms-resistance)} \quad (6)$$

$$G = mg \quad (7)$$

$$\alpha = 10.74\% \quad (8)$$

5.3 Accelerate Performance

Simulation curve

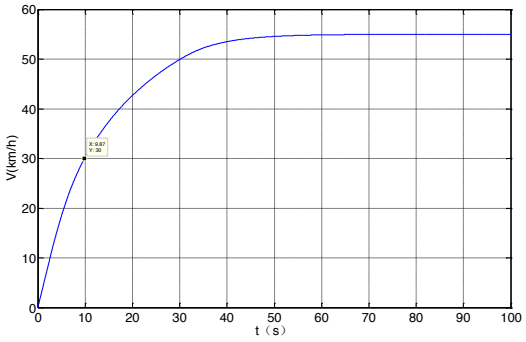


Figure 7: accelerate curve

0-30km/h accelerates time: 9.87s.

6. Experiment Confirmation

6.1 Purposes

The test purpose is through the drum for maximum speed and 0 ~ 30km/h's acceleration time, Maximum grade ability test evaluate Low-speed round drum motor fuel cell vehicles (LWP sight-seeing wind cars) dynamic property.

Through the vehicle in the drum on related conditions, Test batteries for 25% of SOC of actual consecutive trip mileage and total trip mileage by FCE From the 35Mpa to 2Mpa evaluating low-speed round drum motor fuel cell vehicles economic efficiency.

6.2 Test Procedure

6.2.1 Climbing Test

1. The test vehicle loading test quality
2. Set gradient parameters, record the odometers readings and vehicle charge
3. drivers step on accelerate pedal, stable climb hills about 1 minute, records climbing speed
4. parking
5. For the climb tested by the slope is set to 15%

6.2.2 Highest Speed Tests

1. Vehicles start reading, odometers record and vehicle state of charged

2. Drivers will accelerate gradually to maximum speed
3. Stable running about 1 minute with a top speed
4. Stop
5. Through the drum tester, record the highest speed
6. Repeat the above steps twice, take average 3 times as the final result

6.2.3 0—30km/h Accelerate Time Test

1. Vehicles start reading, odometers record and vehicle state of charged
2. Drivers trample accelerator pedal quickly, hurry speed to 30km/h above
3. Slow fall speed
4. Stop
5. Through the drum tester, record the recorder 0 ~ 30km/h acceleration time
6. Repeat the above steps twice, take average 3 times as the final result

6.3 Result

Figure 7: LWP11

Drum performance tests

1. Climbing tests

Table 9: Climbing tests result

A drum set gradient（%）	10%
The initial charged (v)	130.8

2. 0—30km/h Accelerating performance tests

Table10:0—30km/h Accelerating performance tests result

Serial number	1	2	3	average
Acceleration time (s)	11.6	11.6	11.5	11.6

3. Highest speed tests

Table 11: Highest speed tests result

Serial number	1	2	3	average
Highest speed (km/h)	44.1	43.5	43.0	43.5

7. Conclusions

Experimental results demonstrate the wheel motor speed hybrid dynamic performance is Accord with the requirement of the theoretical simulation.

Reference

[1].chen yinda. Fuel-cell cars status quo and develop trend. 1006-5377（2002）01-02-0026-01.《China's environmental protection industry》1-2.

[2].Hongwei.Gao, Ynmin.Gao, Mehrdad.Ehsani. A Nature Network Bassed on SRM Drive Control Strategy for Regenerative Braking in EV and HEV. 0-7803-7091-0/01/S10 2001IEEE:571-575.

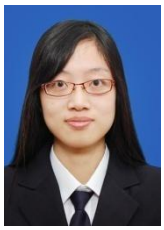
[3]. zhangjian, wang yaonan, caosongbo. Based on fuzzy logic electric automobile braking energy feedback control strategy.colum18(7)，2005. Industrial control computer59-61.

[4]. Zhong zaimin, wei xuezhe, sun zechang. Fuel cell vehicle powertrain control strategy. colume32(6),2004. Tongji university（Natural sciences）758-761.

[5]. Barnard R H. Jefferso C M. criteria for sizing the prime mover and energy storage capacity in hybrid vehicles [A]30th ISA TA conference on Electric and Hybrid Vehicles[C] Florence:ISA-TA,1997.363-369.

Author

xiong yun
Tel:13816571396
Fax:021-51650002
Email:xiongyun@fcv-sh.com



Han-mo Zhao
Tel: 15000600025
Fax: 021-51650002
Email:zhaohanmo@fcv-sh.com

Ting-ting Yin
Tel: 15000568539
Fax: 021-51650002
Email:yintingting@fcv-sh.com