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Development and simulation of electric vehicle based on ADVISOR

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Abstract: Based on the electric vehicle simulator ADVISOR (advanced vehicle simulator), the electric vehicle which has a wheel driving system was developed and named ELVEC. The ELVEC consists of wheel, axle, body, motor/controller, energy storage, power bus, etc. The acceleration, grading, driving speed and fuel economy of the ELVEC are analyzed. The results show that the ELVEC has good dynamic performance and fuel economy. It is suitable for the driving conditions of the start-accelerate-stop and the low speed driving conditions in urban areas. At the same time, the motor performance, energy storage (batteries) and energy management of the ELVEC are simulated. It is concluded that the efficiencies of the motor, batteries and driveline are high, and the energy management and the fuzzy logic control strategy are efficient.

Key words: electric vehicle; motor; dynamics; ADVISOR

The advanced vehicle simulator, better known as ADVISOR, is simulation software that is developed in the environment of the Matlab/Simulink by the National Renewable Energy Laboratory founded by the United States Department of Energy. Through a simple physics model, it uses all assemblies tested for performance to build both conventional and advanced vehicle configurations. It is good at simulating vehicle dynamic performance, vehicle mechanisms, power matching, power combination and drive cycle, and it is also useful for electric vehicle test and development. This paper focuses on the development and simulation of a new electric vehicle by using the ADVISOR[1-2].

1 Vehicle Modeling

There are two ways to choose the vehicle transmission in the ADVISOR. One way is to choose and modify a suitable electric vehicle saved in the ADVISOR; the ADVISOR has saved 37 electric vehicles data including the Insight and the Prius. The other way is to use transmission models to design new transmissions; the ADVISOR has saved eight kinds of transmissions, which include conventional vehicle, battery electric, fuel electric, hybrid electric, etc. Any vehicle model in the ADVISOR includes two main elements: the controlling block diagram and the vehicle and component input data.

In this paper, an electric vehicle named EVLEC has been developed. The EVLEC is driven by the wheel (see Fig. 1) and chooses the electrical vehicle (EV) model in the ADVISOR[3].

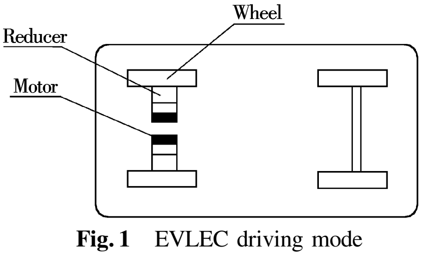

Fig. 1 EVLEC driving mode

1.1 Block diagram

The main block diagram for the ADVISOR model of the EVLEC is shown in Fig. 2. Fig. 2 also illustrates the backward facing architecture of the model.

The EVLEC model includes drive cycle, vehicle, wheel and axle, final drive, motor/controller, electric acc loads, power bus and energy storage. Information flows from the drive cycle speed requirements through the drivetrain to calculate outputs of the electric motor and the energy storage device. Feedback signals of the achievable output for each component are calculated and the power requirements are adjusted based on what was achieved in the previous time step.

1.2 Vehicle input parameters

The vehicle parameters were obtained from the Ford Granada, and the batteries and electric motor parameters were taken from ADVISOR and modified[4-5]. Tab. 1 shows the main input parameters for the EVLEC model, where M_{bh} is the mass of the half vehicle; I_b is the moment of inertia; K_{tf} is the front tire stiffness; K_{tr} is the rear tire stiffness; K_{sf} is the front suspension stiffness; K_{sr} is the rear suspension stiffness; a is the

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distance between front wheel and the center of vehicle mass; l is the wheelbase.

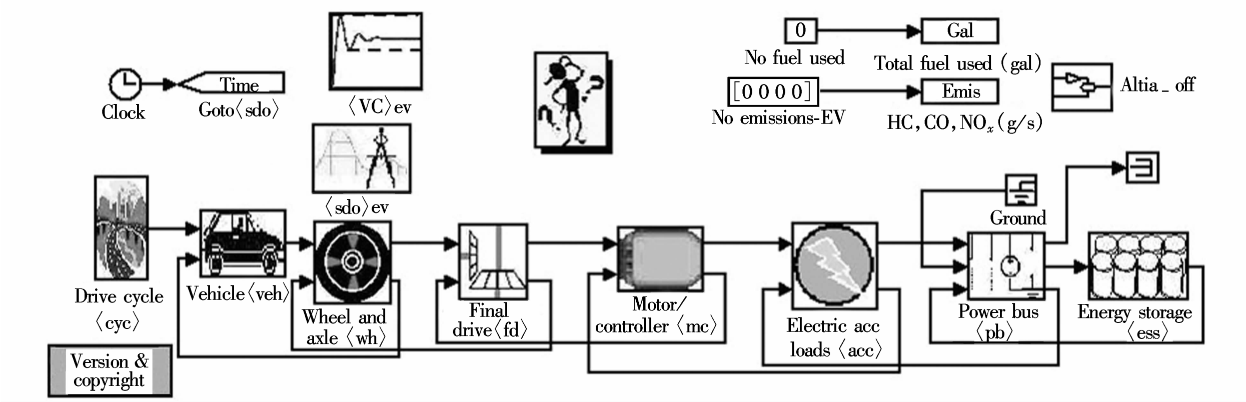

Fig. 2 Main block diagram for the ADVISOR's EVLEC model

Tab. 1 EVLEC major parameters

Vehicle parameters							
M_{bh}/kg	I_b/(kg·m^2)	K_{tf}/(kN·m^{-1})	K_{tr}/(kN·m^{-1})	K_{sf}/(kN·m^{-1})	K_{sr}/(kN·m^{-1})	a/m	l/m
690	1 222	192	192	17	22	1. 25	2. 76

Electric motor (MC _ AC75)					
Peak power/kW	Peak torque/(N m^{-1})	Rating voltage/V	Over loading/%	Maximum rotate speed/(r min^{-1})	Mass/kg
58(7 000 r/min)	110(1 ~ 7 000 r/min)	288(max 480)	300	11 000	50

Battery			Tire		
Battery type	Cell voltage (nominal)/V	Number of battery	Tire type	Mass/kg	Radius/m
NIMH	14	26	Michelin proxima P175/65 R14	40. 5	0. 282

2 Analysis of Electric Vehicle Performance

After the EVLEC simulation model has been built and vehicle parameters have been set by modifying the Matlab file, the simulations have been finished. The ADVISOR allows for simulations of all the chassis dynamometer test procedures as well as many other standard drive cycles, and any user defined cycles. In the simulation, the drive cycle chooses CYC _ UDDS drive cycle from the ADVISOR. It simulates the urban traffic environment, and it is suitable for small vehicle tests and measuring vehicle performance[6-7].

2. 1 Dynamics of the electric vehicle

1) Acceleration performance

Tab. 2 shows the EVLEC acceleration performance simulation results. It has good acceleration performance and is close to the conventional vehicle. The acceleration time of the speed from 0 to 96. 6 km/h is less than 11 s. The EVLEC maximum acceleration is 3. 45 m/s^2 which is short at overtaking and is affected by battery discharge depth and power density. The acceleration performance can be improved by using high-powered batteries.

2) Grading capability

At a speed of 55 km/h, the EVLEC grading capability is 10% and is not enough. It is only suitable for level roads in urban areas. The reason is that the energy saved resource cannot supply superfluity power. To overcome the disadvantages of the vehicle, one way is to add a parallel auxiliary energy resource. When the vehicle climbs, the energy resource can supply superfluity power, but it will increase vehicle weight and affect acceleration performance.

Tab. 2 Acceleration of EVLEC electric motor vehicle

Speed/(km·h^{-1})	Acceleration time/s
0 to 96. 6	10. 67
40 to 60	6. 39
64. 4 to 96. 6	4. 46

3) Speed

Fig. 3 shows most of the time EVLEC speed is lower than 50 km/h and the maximum speed is 106. 2 km/h. The vehicle satisfies the lower speed and often the start-accelerate-stop drive conditions in urban areas.

2. 2 Analysis of the EVLEC economy

To compare the energy efficiency of electric vehicles and conventional vehicles, the electric power consumption will be transferred to the gasoline consumption by

$$M_{MPG} = E_e G \eta \tag{1}$$

where M_{MPG} is the driving mile of every gallon gasoline, E_e is the electric vehicle energy efficiency, G is the coef-

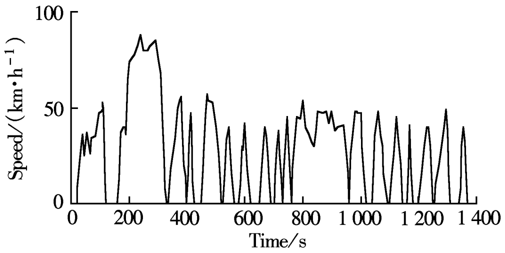

Fig. 3 Drive cycle

ficient of the electric power transferring to every gallon of gasoline, and η is the ratio of electric vehicle system efficiency and conventional vehicle efficiency.

Using Eq. (1), the EVLEC correspondent fuel consumption can be calculated. Tab. 3 shows the result and two conventional vehicle fuel consumptions. It is concluded that electric fuel economy is better than that of a vehicle of the same class. If the energy storage flywheel has been used and the braking energy has been regenerated by using regenerative energy power, the economy will be better.

Tab. 3 Fuel consumptions of EVLEC and conventional vehicles

Vehicle	Power	Fuel economy/($km \cdot L^{-1}$)
Ford Escort	Gasoline	28. 40
Dodge Caravan	Gasoline	20. 60
EVLEC	Electric	32. 90

2. 3 Motor performance

EVLEC uses the MC _ AC75 motor used by GM EV1. Its average efficiency is lower than 83. 4% and far higher than that of a fuel engine used by a conventional vehicle. Fig. 4 illustrates that in the lower rotate speed range the motor has greater torque and can satisfy the requirements of the vehicle starting, accelerating, and grading. In the high speed range, the torque is lower. In the common range (4 000 to 8 000 r/min), the motor efficiency is higher than 85%. That means that the electric vehicle efficiency is superior to the conventional vehicle.

The motor maximum torque is 150 N · m, but most of the time the torque is lower than 50 N · m. The vehicle does not take advantage of high torque of

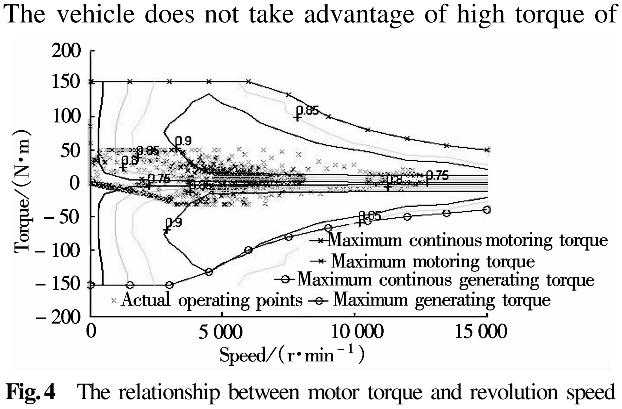

Fig. 4 The relationship between motor torque and revolution speed

the motor. There are two reasons. One is that the simulation chooses the CYC _ UDDS(urban drive cycle). The grade is lower and does not need high torque. The other is that the motor is affected by the battery discharge depth and power density. When the vehicle grades or accelerates, the motor needs enough power to support the high power and high torque state.

2. 4 Energy storage and power bus

EVLEC chooses NIMH batteries as an energy resource. Fig. 5 illustrates that the high power is 100 kW at 20% of the state of charge and is close to the maximum power 140 kW at 60%, so the vehicle will fast charge. The charge process is stable and the power smoothly increases. Fig. 6 shows that when the depth of discharge is lower than 40%, the battery pulse power can exceed 130 kW. That will provide the power needed by the electric vehicle to grade or accelerate. When the depth of discharge exceeds 50%, the pulse power decreases linearly, and the vehicle cannot have enough pulse power to grade or accelerate.

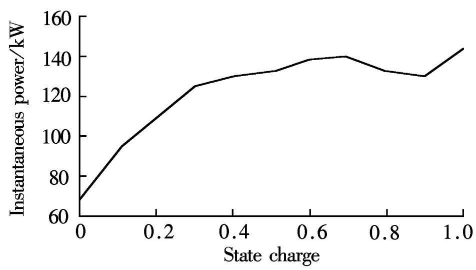

Fig. 5 The relationship between state charge and instantaneous power

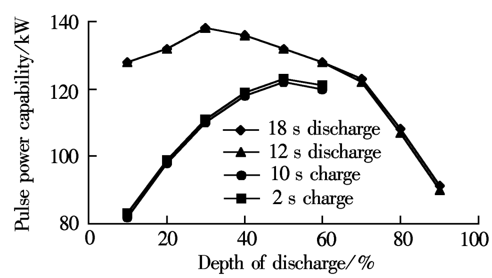

Fig. 6 The relationship between depth of discharge and pulse power capability

The ADVISOR provides parallel electric assist, adaptive control strategy, fuzzy logic control strategy, Honda Insight control strategy and so on. The EVLEC model chooses fuzzy logic control strategy, and the strategy includes optimizing the cooperation among the assemblies. It is useful to increase driving miles and improve electric vehicle performance of each charge by reasonably controlling and distributing the energy resources according to the fuzzy logic control strategy[8].

Tab. 4 shows the simulation results of the EV-

LEC efficiency. It is concluded that the efficiency of the driveline, motor, and batteries etc. is high, and the energy management and the fuzzy logic control strategy are efficient.

Tab. 4 EVLEC efficiency %

Driveline average efficiency	83. 3817
Motor/inverter average motoring efficiency	87. 611 1
Motor/inverter average generating efficiency	83. 811 2
ESS average discharge efficiency	97. 850 8
ESS average recharge efficiency	96. 149 9
ESS average round-trip efficiency	94. 083 4

3 Conclusion

The electric vehicle EVLEC has been designed and the simulation model has been built by using the ADVISOR. The simulation results predict that the vehicle has good performance. Especially, it has good fuel economy. In the lower rotate speed range the motor has greater torque and can satisfy the requirements of the vehicle starting, accelerating, and grading. In the common range (4 000 to 8 000 r/min), the motor efficiency is higher than 85%. When the depth of discharge exceeds 50%, the pulse power decreases linearly, so the vehicle cannot have enough pulse power to grade or accelerate. The energy management is efficient in energy distribution and management and is much better than that of the conventional vehicle.

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基于 ADVISOR 电动汽车的开发和仿真

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摘要:基于电动汽车仿真软件 ADVISOR,开发了双电机分散驱动轮式电动汽车 ELVEC. ELVEC 由车身、电动机、能量管理和能量存储(电池组)等模块组成. 进行了 ELVEC 电动汽车的加速性能、爬坡能力、行驶车速和燃料经济性的分析. 结果表明,该车具有良好的动力学性能和燃料经济性,适合在低速、频繁启动的市区内行驶. 同时,对电动机特性和能量存储(电池组)及能量管理特性进行了仿真分析,得出 ELVEC 电动汽车的电动机、电池和驱动系统等均具有较高的效率,能源管理系统和模糊逻辑控制在能量的分配、管理上十分有效.

关键词:电动汽车;电动机;动力学;ADVISOR

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