Research on ADVISOR-Based Fuzzy Logic Control Strategy for HEV Vehicles

Jiang chaoyu[1, a*], Shen lizhon[2,b], Yang xueping[3,c]

[1]Automotive Technical Engineering Department, Yunnan Mechanical and Electrical Professional Technology Institute, Yunnan, China

[2]Yunnan Province Key Laboratory of Internal Combustion Engine, Kunming University of Science and Technology, Yunnan, China

[3]Automotive Technical Engineering Department, Yunnan Mechanical and Electrical Professional Technology Institute, Yunnan, China

*Corresponding author

Keywords: HEV, fuzzy logic control, ADVISOR, simulation

Abstract: In order to study the influence of control strategy on the performance of parallel hybrid electric vehicle (HEV), the input membership function is the current motor speed, the difference of engine optimal torque and the SOC of battery charge state, and the real-time output torque factor K is taken as the output membership function. A fuzzy logic control strategy is proposed. The fuzzy logic control strategy module is embedded in the ADVISOR software to study the difference between the Electro-assisted control strategy. The results show that the fuzzy logic control strategy is better than the Electro-assisted control strategy in economy, emission, transmission efficiency, battery SOC life and stability. In dynamics, the fuzzy logic control strategy has stronger climbing ability, and the Electro-assisted control strategy has better acceleration ability.

1. Introduction

With the increasingly prominent problems of energy and environment, new energy vehicles have become the focus of development today. Considering that hybrid vehicles have the advantages of traditional fuel vehicles and pure electric vehicles, parallel hybrid vehicles can give full play to the performance of engines and batteries [1-3]. As the research of the parallel hybrid vehicle, the control strategy is the most important part. In the control method of parallel hybrid electric vehicle (HEV), one of the main goals is to make the engine work in the peak efficiency area to improve the overall efficiency of the powertrain.

In the traditional parallel hybrid electric vehicle, the common parallel electric power control strategy is used. The main idea is to use the engine as the main driving source of the vehicle, and the motor driving system is only used as the auxiliary driving source. The motor plays a role of peak shaving and valley filling for the output torque of the engine, at the same time, the SOC value of the battery pack is guaranteed to be within a certain range [4]. However, this kind of power distribution does not give full play to the advantages of hybrid drive, because the efficiency of hybrid drive system is not only related to the efficiency of engine operation, but also affected by the efficiency of battery and motor. Therefore, in the process of energy distribution, it is necessary to use fuzzy logic to control the engine, battery and motor to optimize their overall work efficiency.

Considering the highly nonlinear and time-varying characteristics of the vehicle, a fuzzy logic controller is proposed to control the engine, motor and battery.

2. Design of Fuzzy Logic Control Strategy

2.1 Fuzzy Control Module

The starting point of designing the fuzzy logic control strategy is to consider the influence of the current motor speed on the working condition of the engine, and realize the balance of battery

  DOI: 10.25236/mmmce.2020.002

charge and discharge on the premise of ensuring the highest fuel efficiency of the engine. In the fuzzy logic controller, multiple input and output membership functions can be formulated, and the required fuzzy control rules can be generated according to certain rules. The fuzzy logic controller has three signal input membership functions: the current speed of the motor Nm, SOC value of the battery state of charge and the difference △T of the optimized torque of the engine. Based on the above three input signals, the fuzzy logic is used to determine the factor K of engine output torque. The total control module is shown in Figure 1

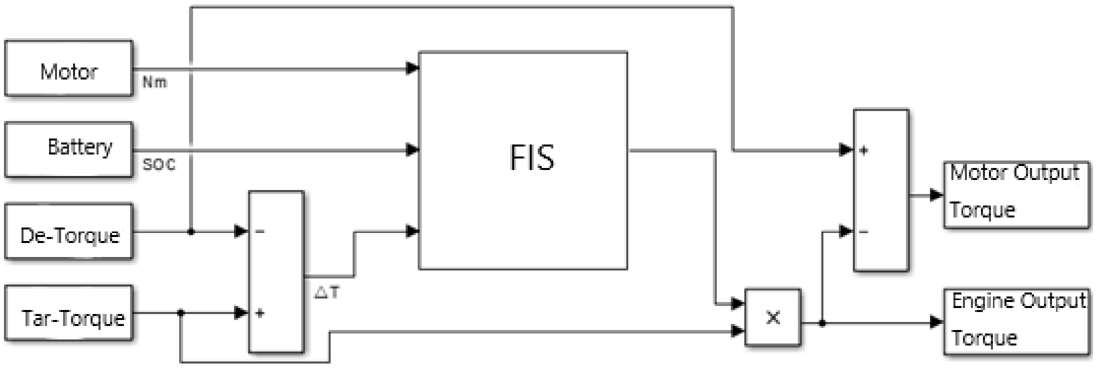


Figure 1 fuzzy control module

The target torque of the engine is a curve which interpolates and connects the minimum specific fuel consumption point of the engine under the current speed condition from the universal characteristic curve of the engine under the static condition, that is to say, taking the minimum specific fuel consumption as the target function and programming with m file. The torque range of the engine is different at different speeds. Therefore, the difference △T Between the total torque and the optimized torque is used as the output parameter to control the working range of the engine [5-8]. The actual torque of the engine can be obtained by the fuzzy logic controller. The torque of the motor can be obtained by the difference between the total torque and the required torque of the engine.

2.2 Design of Fuzzy Logic Controller

In the MATLAB fuzzy logic toolbox, all the links of the design of the fuzzy reasoning system are provided, including the definition of input and output control variables, the design of membership functions and the editing of control rules. At present, there are two kinds of fuzzy reasoning methods in MATLAB fuzzy logic toolbox, Mamdani and Sugeno. In many aspects, their reasoning is similar. The main difference is that the membership function of Sugeno's reasoning output is linear or constant, which is a special type. It combines the de fuzzification into fuzzy reasoning, and the final output is the accurate quantity [9-10]. As the output of the fuzzy logic controller is represented by a single valued function, the Sugeno type of reasoning method is adopted, as shown in Figure 2.

The input variables of the fuzzy logic controller in this system are the torque difference △T and battery SOC, the current speed of the motor Nm, the output variable is the coefficient K, and the input variable △T is described as{‘negative big’, ‘negative small’, ‘zero’, ‘positive small’, ‘positive large’}, the input variable SOC value is described as{‘too low’, ‘too low’, ‘moderate’, ‘too high’, ‘too high’}, the current motor speed Nm is described as{'Lower', 'Higher'}, the membership functions of the input variables are shown in Figure 2 and Figure 3, respectively. The output variable K value is {0, 0.05, 0., 10, 0.15, 0.20, 0.25 ... 1.80, 1.85, 1.90, 1.95, 2.00, 2.05}, The membership functions of the input variables are shown in Figure 3.

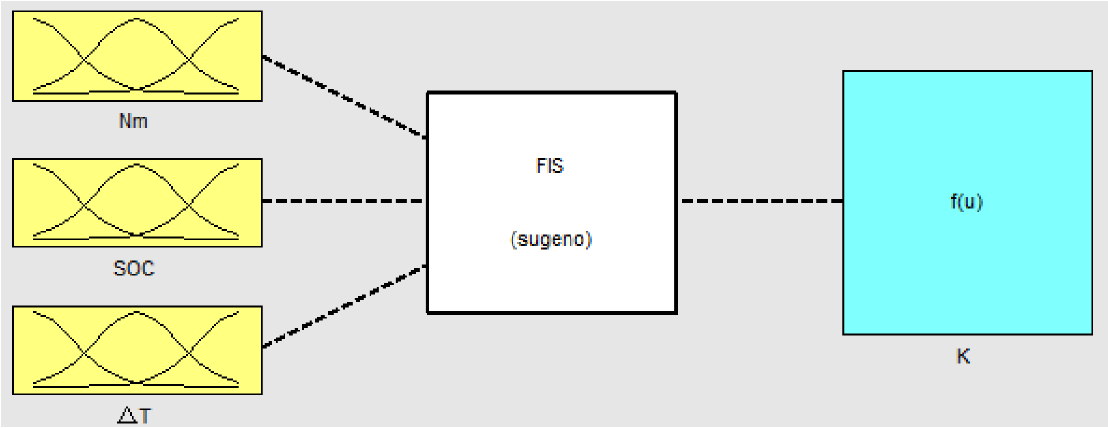
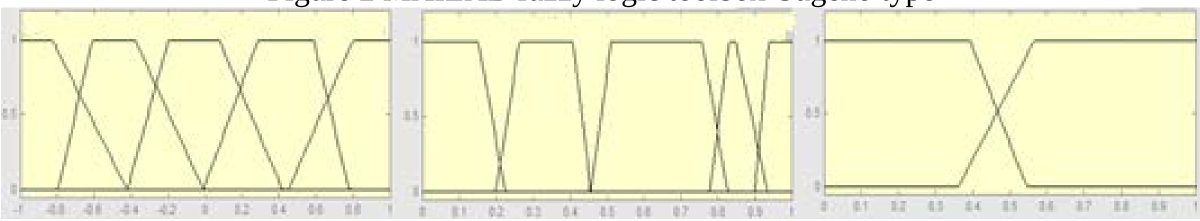


Figure 2 MAILAB fuzzy logic toolbox-Sugeno type


a. Soc membership function b. Nm membership function c. △T membership function
Figure 3 membership function of input variables

In the fuzzy logic control strategy, the "if-then" structure is adopted, such as: "if Nm is low, and △Tis negative, and SOC is too low then K is 0.45; if Nm is high, and △T is large, and SOC is too low, then K is 2.00; etc. ", to ensure that the battery is in the process of charge and discharge balance, Make the engine working torque in the most fuel-efficient area. This establishes multiple rules as shown in Table 1.

Table 1 Fuzzy control strategy rules

N_m	SOC	△T				
		Negative big	negative small	zero	positive small	positive large
Lower	too low	0.45	0.85	1.25	1.65	2.05
	low	0.35	0.75	1.15	1.55	1.95
	moderate	0.25	0.65	1.05	1.45	1.85
	high	0.15	0.55	0.95	1.35	1.75
	too high	0.05	0.45	0.85	1.25	1.65
Higher	too low	0.40	0.80	1.20	1.60	2.00
	low	0.30	0.70	1.10	1.50	1.90
	moderate	0.20	0.60	1.00	1.40	1.80
	high	0.10	0.50	0.90	1.30	1.70
	too high	0.00	0.40	0.80	1.20	1.60

3. Fuzzy Logic Control Strategy Simulation Analysis

After the design of the fuzzy logic controller is completed, the construction of the control strategy module needs to be completed in SIMULINK as shown in Figure 4. After building the fuzzy control module, the secondary development of ADVISOR, the built fuzzy control strategy is embedded in the top-level module of simulation software ADVISOR (as shown in Figure 5) for calculation.

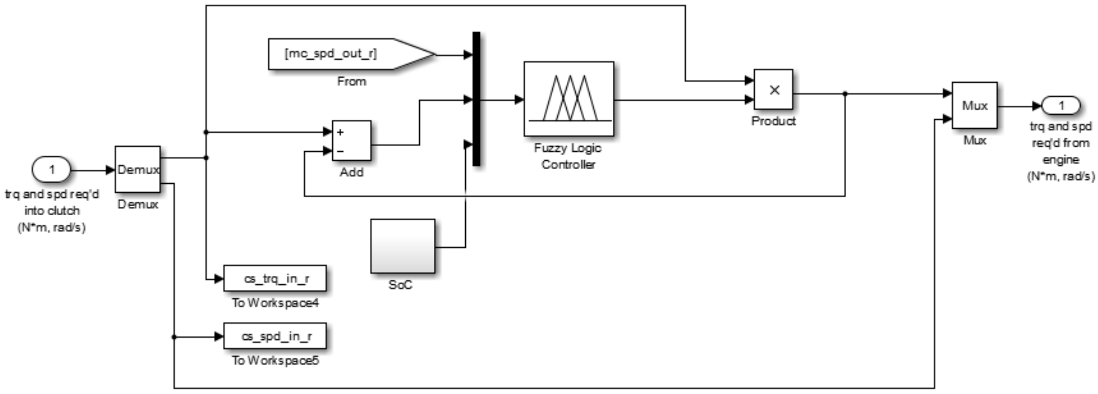


Figure 4 SIMULINK fuzzy logic control strategy module

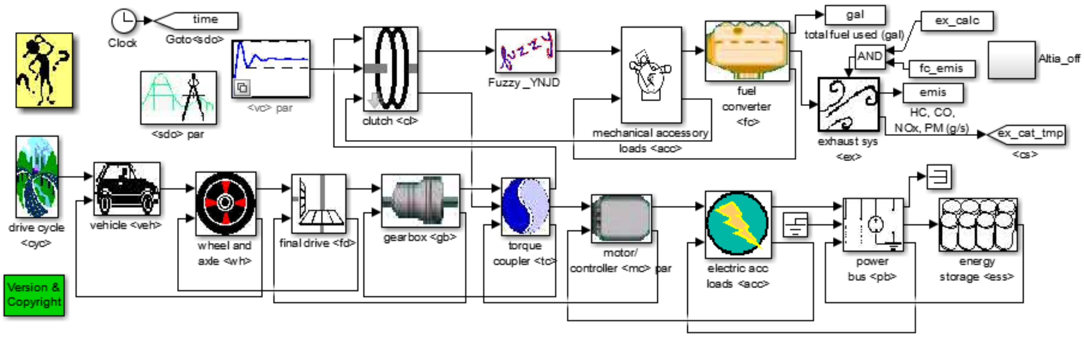


Figure 5 HEV top-level module structure

After the fuzzy control strategy is embedded in the software, the effect of the motor assisted control strategy and the fuzzy logic control strategy can be compared. In the simulation process, the selected PHEV model parameters are shown in Table 2, and the working conditions are respectively selected from the urban road cycle (CYC_UDDS) customized by EPA of the United States Environmental Protection Agency, and the European urban road cycle (CYC_ECE_EUDC), In order to ensure the accuracy of the simulation results, three groups of superposition methods are selected for simulation at the same time under the two working conditions. Under the condition of ensuring the same other input parameters, the performance results of PHEV under the control of the two control strategies are compared as shown in Table 3 and the state change of battery SOC is shown in the figure.

Table 2 main parameters of PHEV

Vehicle parameters	value	Engine parameters	value	Motor parameters	value	Battery parameters	value
Vehicle mass	1386Kg	Engine injection mode	EFI Gasoline Engine	Rated power	45KW	Capacity	25Ah
Tyre rolling radius	0.28m	Maximum power (speed)	52Kw （4800r/min）	Rated speed	2200r/min	Number	25
Air drag coefficient	0.31	Maximum torque (speed)	98N.m （4800r/min）	Maximum speed	8000r/min		
Windward area	1.8m^2			work efficiency	0.91		

Table 3 performance simulation results of HEV

Cycle type	Control strategy	Dynamic		Economy	Emission			Transmission efficiency /%
		0-60km acceleration time/h.s	10km/h climbing slope/%	Fuel consumption per 100 km/L	HC	CO	NO_X	
CYC_UDDS	fuzzy control	9.0	31.8	15.4	0.321	1.281	0.270	8.7
	electric auxiliary control	8.5	30.8	15.6	0.325	1.296	0.281	8.5
CYC_ECE_ EUDC	fuzzy control	9.0	31.8	17.4	0.316	1.390	0.242	11.4
	electric auxiliary control	8.5	30.8	17.7	0.331	1.403	0.261	11.4

4. Result Analysis

4.1 Performance Analysis of Engine and Motor

In terms of dynamic performance: compared with the electric auxiliary control strategy, the fuzzy logic control strategy takes longer time in the acceleration process of 060km, with an average acceleration time of 5.8% more, and the acceleration ability is weak; however, the climbing ability is better, and the climbing degree exceeds 3.2% in the process of 10km / h. The two control strategies have their own advantages in power performance. The fuzzy logic control strategy is better in the climbing ability of hybrid electric vehicle, and the electric assistant control strategy is better in the acceleration ability of hybrid electric vehicle.

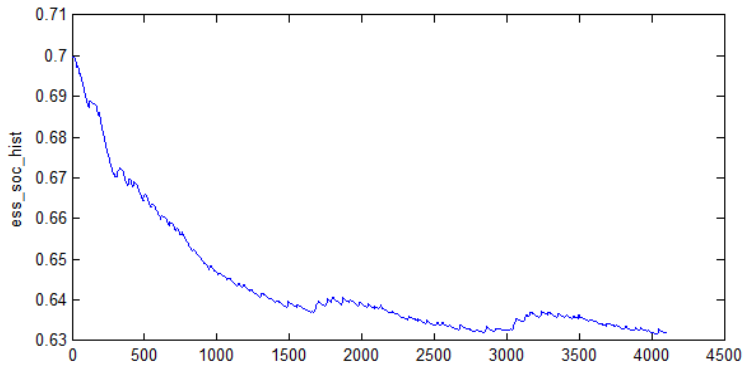
In terms of economy: under the two conditions, the fuel consumption of hybrid electric vehicle with fuzzy logic control strategy is better than that of electric auxiliary control hybrid electric vehicle in terms of 100 km fuel consumption. Under the condition of CYC_UDDS, the fuel consumption is reduced by 1.3%; under the condition of CYC_ECE_EUDC, the fuel consumption is reduced by 1.7%.

In terms of emissions: in two working conditions, the fuzzy logic control strategy of hybrid electric vehicle compared with the electric assistant control hybrid electric vehicle has a significant reduction in the emissions of three pollutants, especially in the CYC_ECE_EUDC working condition, the decline is significant.

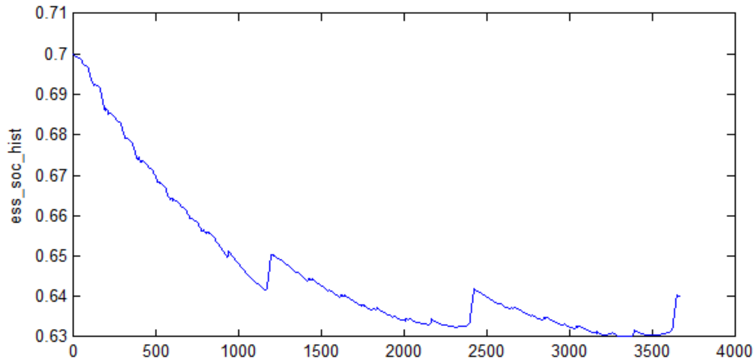
For the transmission efficiency: under the CYC_UDDS condition, the transmission efficiency of the fuzzy logic control strategy hybrid electric vehicle is higher than that of the electric assistant control hybrid electric vehicle, and the transmission efficiency is increased by 2.4%; under the CYC_ECE_EUDC condition, the transmission efficiency of the two is basically the same.

4.2 Battery Performance Analysis

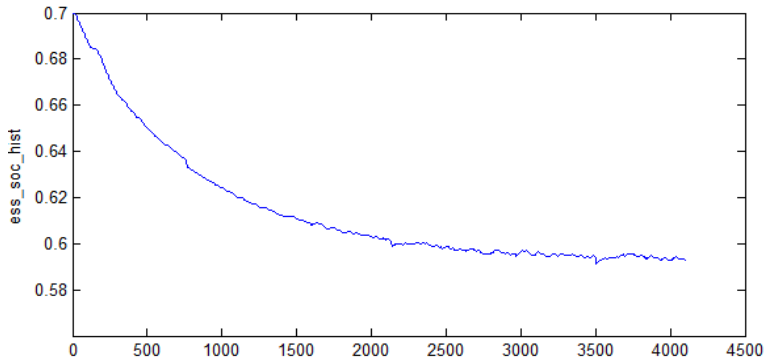
The battery performance analysis is shown in the figure. It can be seen from the figure that the SOC at the beginning of the battery is 70% under both working conditions. After the end of the cycle, the final SOC value of the battery under the same control strategy does not change significantly; while under the same working condition, compared with the electric auxiliary control strategy, the final SOC value of the battery is closer to the initial value and the battery consumption is smaller, which can better ensure the battery life.



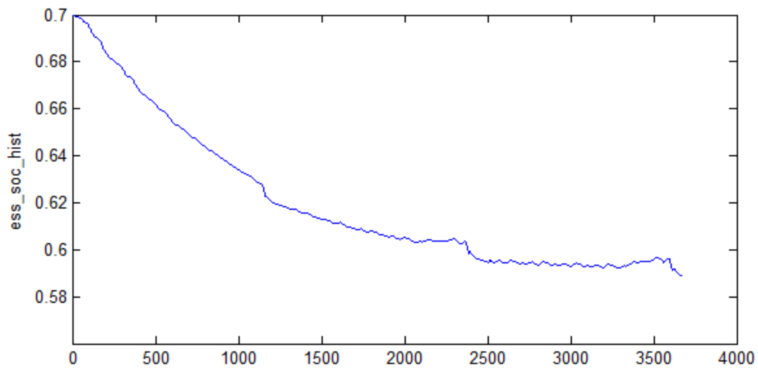
SOC under CYC_UDDS fuzzy logic control



SOC under CYC_ECE_EUDC fuzzy logic control



SOC under CYC_UDDS electric auxiliary control



SOC under CYC_ECE_EUDC electric auxiliary control

Figure 6 change of battery charge state under two working conditions

5. Conclusion

According to the parallel hybrid electric vehicle, the simulation research is carried out by using the self-defined fuzzy logic control strategy instead of the electric auxiliary control strategy. The results show that compared with the electric auxiliary control strategy, the fuzzy logic control strategy of the hybrid electric vehicle improves the economy, emission, transmission efficiency, battery SOC life and stability to a certain extent. In terms of power, the model the climbing ability of fuzzy logic control strategy is strong, and the acceleration ability of electric auxiliary control strategy is good.

Acknowledgement

Basic Research Youth Project of Yunnan Provincial Department of Science and Technology (2018FD050)

References

[1] Ma Shaodong, Yang Shichun. Modeling and Simulation of composite power supply for armored vehicles based on advisor [J]. Computer simulation, 2018, (5): 17-21.

[2] Zeng Xiaohua, Wang Qingnian, Li Jun, et al. Development of control strategy module for hybrid electric vehicles based on advisor 2002 [J]. Automotive engineering, 2004, (4): 394-396416.

[3] Zhang Chuanwei, Li Chenxi. Simulation of regenerative braking control strategy of mine trackless rubber wheel electric vehicle based on advisor [J]. Coal technology, 2014, (6): 196-198.

[4] Tan Derong, sun Jingxia, Wang Xingwei. Research on plug inhev fuzzy control based on advisor secondary development [J]. Journal of Chongqing Jiaotong University (NATURAL SCIENCE EDITION), 2011, (5): 1054-1058.

[5] Qin Dongchen, peidongjie, Chen Jiangyi, Et al. Power system simulation of coaxial hybrid vehicle based on advisor [J]. Journal of Zhengzhou University (Engineering Edition), 2013, (6): 120-124.

[6] Gong Xiangyu, Zhang Lei. Integrated control of CVT vehicle speed ratio based on advisor [J]. Computer simulation, 2007, (1): 258-261, 290. [7] KARABASOGLU O，MICHALEK J· lnfluence of driving patterns on life cycle, post and emission of hybrid plug-in intensive power trains [J]. Energypolicy, 2013, 60:445-461.

[8] Pal T，Pat N R，PalM．Learning fuzzy rules for controllers with genetic algorithms [J]. International Journal of intelligent system, 2003 (18): 569-592.

[9] Lei Xiao, Dai Chaohua, Chen Weirong, et al. Modeling and Simulation of fuel cell hybrid locomotive based on advisor [J]. Power technology, 2015, (12): 2643-2646.

[10] Zeng Xiaohua, Wang Qingnian, Li Sheng, et al. Integrated development of forward simulation model and reverse software advisor [J]. Automotive engineering, 2007, (10): 851-854