An Analysis of Electric Assist Control Strategy for Hybrid Electric Vehicles and Simulation

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Abstract

The paper presents an analysis of electric assist control strategy for hybrid electric vehicles and makes an analysis of simulation on advisor platform.

Keywords

HEV, control assistant strategy, simulation, analysis

1. INTRODUCTION

The hybrid electric vehicle (HEV) has an electric driving system in addition to a traditional internal combustion engine vehicle, two driving systems work together according to a control strategy to achieve the lower emissions of electric vehicles and the higher energy density of a traditional internal combustion engine vehicle. In the condition that there is no material breakthrough of battery technology, it has become an important developing direction of automobile industry.

An electric assist control strategy has been widely used in current hybrid electric vehicles. Its characteristic is simple control logic and easily achieved but without realizing optimization of fuel economy. This paper presents an analysis of electric assist control strategy for hybrid electric vehicles and makes an analysis of simulation on advisor platform.

2. ELECTRIC ASSIST CONTROL STRATEGY

The main targets of the control strategy for hybrid electric vehicles include:

1. to guarantee the dynamics performance of vehicles.
2. to achieve an ideal fuel economy and emission performance as much as possible.
3. to keep the SOC of battery in the optimization area , avoiding charging on the ground so as to keep range.

Figure 1 shows the principle of electric assist control strategy, Td and Te represents the whole required driving torque and engine torque separately. Therefore motor torque can be expressed as the vector margin of Td and Te (positive for motoring and negative for generating), namely, Tm=Td-Te.

In Figure 1, arrows mark the engine working and halting area. We can see that the minimum torque line and

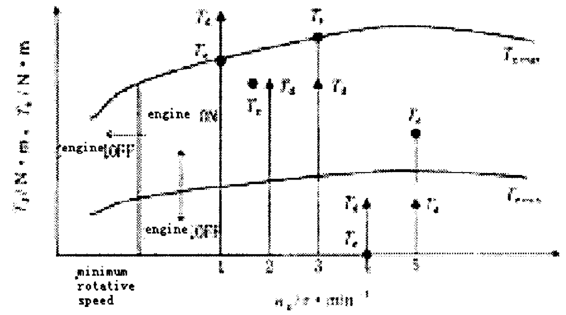

Fig. 1 Electric assist control strategy diagram

minimum speed line form the boundary of the engine running and shut-off area. Moreover, the maximum torque line represents the upper limit of load of engine. Five typical driving conditions are listed on the transverse axes [Yanbo et al., 2003]:

1. Hybrid driving mode and the motor is used for torque assist if the required torque is greater than the maximum producable by the engine at the engine's operating speed;
2. When SOC>SOCmin and Td being medium, only engine works;
3. When SOC<SOCmin and Td being medium, engine woks in the maximum torque to provide excess torque which will be used by the motor to charge the battery;
4. When Td<Temin and SOC>SOCmin, pure electric driving mode;
5. When Td<Temin and SOC<SOCmin, engine will work with the minimum torque;

Moreover, there is regenerative braking and a pure electric starting mode.

According to the above analysis, electric assist control strategy tries to make engine operating in higher efficiency area by controlling the minimum speed and torque limits of an engine to drive the vehicle. But the motor will assist in conditions of lower or higher load to provide electric driving. Here, electric driving functions resolving bad emissions for low load and insufficiency of power for higher load.

Electric assist control strategy didn't take the influence of motor and. battery efficiency in account. But it still will bring about a better result if the following factors are right set:

According to the chosen engine and motor, a minimum speed and torque should be optimum and a correct hybrid ratio is needed.

If the minimum rotate speed of engine is set too low, namely, even when not in economy area, the engine is still needed to work. On the other hand, if the initial speed is set too high, a larger power motor and corresponding battery is necessary, which means a higher cost, but it is a trend to increase the power of motor and hybrid ratio appropriately to get more electric driving for improving fuel economy and emission, of course still restricted by the current battery technology [Leng, et al., 2003].

On advisor platform, the engine's minimum torque is decided according to engine MAP, and on the basis of the highest rotate speed, we can get the maximum torque of the engine, which by multiplying a factor is the engine's minimum torque. Its simulation model shows in Figure 2. The factor will influence the state of engine and motor. If the factor is too large, the engine will get more chances to work in a high efficiency region and a larger power motor and battery is needed. In this hybrid system, motor work in electromotor state most of the time, so SOC of battery is declining to a minimum SOC and maintaining. On the contrary, if the decided minimum torque is too small, fuel economy will drop.

According to engine efficiency MAP Figure 4 and motor efficiency MAP Figure 5 as well as battery charging and discharging efficiency, we can see engine efficiency is relatively lower than that of motor. Functions showed as followed:

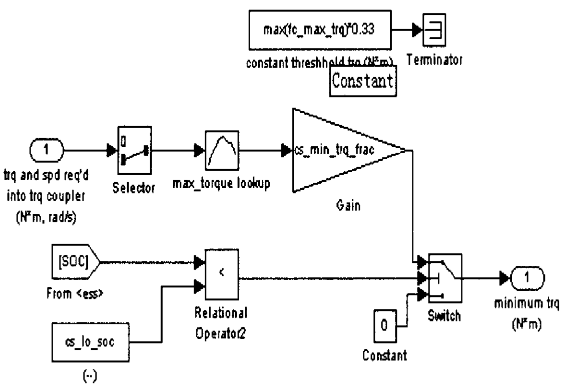

Fig. 2 Simulation model on advisor platform

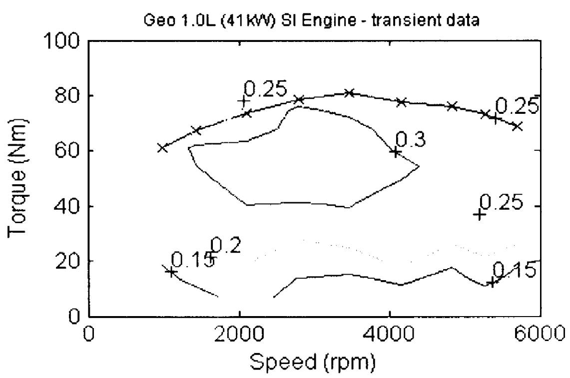

Fig. 3 A 41kw-lc - engine's MAP

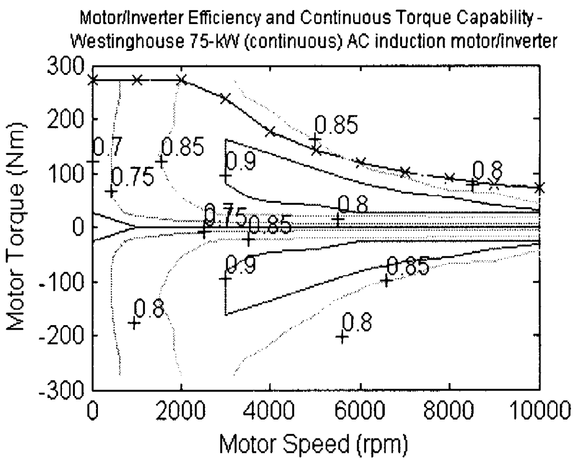

Fig. 4 A 75kw motor's MAP

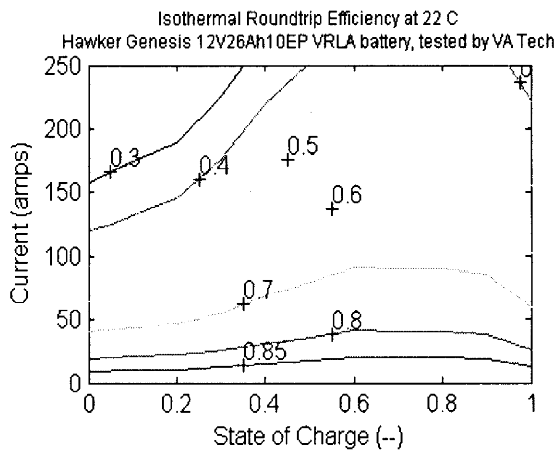

Fig. 5 22℃ a battery charging MAP

$$P1_{eff} = P * \eta_1 \tag{1}$$

$$P2_{eff}=(P - \triangle P) * \eta_2 + \triangle P * \eta_2 * \eta_3 \tag{2}$$

$$P2_{eff} - P1_{eff} = P * (\eta_2 - \eta_1) - \triangle P * \eta_2 (1 - \eta_3) \tag{3}$$

$P1_{eff}$ and $P2_{eff}$ represent the engine effective power of traditional vehicles and hybrid electric vehicles separately, η_1 η_2 for engine efficiency, η_3 for electric driving efficiency (including motor and battery efficiency) and $\eta_1<\eta_2<\eta_3$, $\triangle P$ is for electric driving efficiency getting by power distribute device. As long as the condition of $\triangle P / P < (\eta_2 - \eta_1) / (\eta_2 (1- \eta_3))$ meets, we can get $P2_{eff} > P1_{eff}$, cat the same time, hybrid ratio $\triangle P/P$ should be kept within certain limits because of the maximum torque that the vehicle requires.

3. SIMULATION ANALYSIS

Two parallel hybrid electric vehicles are chosen to analyze, which are separately fitted with CVT and automatic transmission. Other configurations including the engine and battery are the same and initial SOC is set at 0.7. Drive cycle and simulation results are followed in Figure 6 and Figure 7.

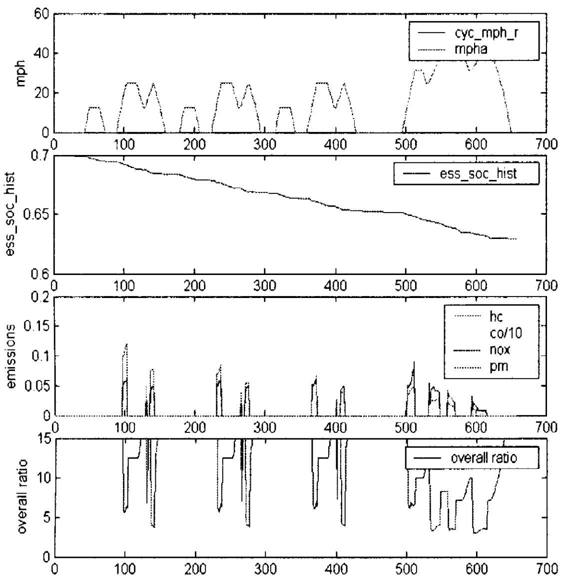

Fig. 6 (CVT) simulation result

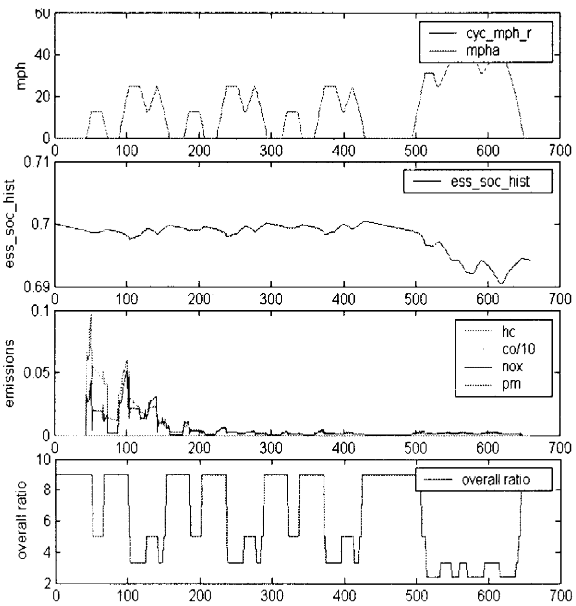

Fig. 7 (Auto transmission) simulation result

By contrast, the vehicle with CVT has a better fuel economy, because CVT will try to adjust the engine to run efficiently and insufficient torque is provided by the motor. So the changing trend of battery SOC is declining all the time till the minimum SOC.

According to Figure 7, the minimum rotation speed is set at low and bad emission shows at the beginning of simulation in Figure 7 and the engine almost works the whole of the drive cycle, so SOC hasn't deleted so much until the vehicle runs at very high speed.

4. CONCLUSION

According to the above analysis, we can draw a conclusion that CVT will help to improve fuel economy to a great content but can't keep the SOC of battery in a driving cycle; and appropriate initial battery SOC and minimum rotation speed of the engine can influence the emission. A correct configuration is needed for the an electric assist control strategy for an ideal control result.

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