International Journal of Science and Engineering Applications
Volume 12-Issue 07, 149 – 151, 2023, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1207.1039

Transmission System Design of Dual-Mode Power-Split Hybrid Electric Vehicle

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Abstract: Based on the introduction of the mechanical structure and working principle of the new compound power-split hybrid electric vehicle, this paper studies the minimum equivalent fuel consumption energy management control strategy based on the minimum principle and builds the model and simulation environment through Simulink. Compared with the traditional internal combustion engine prototype vehicle, the fuel consumption per 100 kilometers under the NEDC cycle condition has significantly improved the fuel economy of the whole vehicle. The results show that the optimal control strategy formulated in this paper can realize the working mode of hybrid electric vehicles and achieve better fuel saving and control effects.

Keywords: Transmission System, Dual-Mode, Power-Split, Hybrid Electric Vehicle

1. INTRODUCTION

According to the power mixing ratio, hybrid electric vehicles can be divided into weak hybrid, medium hybrid, and strong hybrid. Among them, strong hybrid electric vehicles can achieve more than 40% fuel saving effect, which is the focus of research and development of major domestic and foreign automobile companies. Intensity mixing can be divided into two schemes: electromagnetic power splitting through dual-rotor motors and mechanical power splitting through planetary row. Under load conditions, it can run on the best economical operating line without being constrained by the wheel load, thereby saving fuel consumption but having an important impact on the development of the domestic automobile industry.

Honda's IMA motor-assisted transmission system, because its structure is like the traditional automobile transmission system, the cost increase is relatively small, and the fuel-saving effect is obvious. However, the Honda IMA motor-assisted transmission system cannot meet people's pursuit of higher vehicle fuel levels and is limited by the vehicle itself. Therefore, major domestic manufacturers are researching new hybrid vehicle transmission systems with higher fuel efficiency. There must be 2 input or output components. According to the different connection modes between the various components of the planetary gear mechanism and the engine, motor, and generator, it can be combined into 6 different structural schemes.

After the analysis of different structural schemes, the best structural scheme is the power transmission system structure adopted by Toyota Prius; another feasible scheme with slightly worse structural performance than Prius is that the engine is connected with the ring gear, and the motor is connected with the planet carrier. The generator is connected to the sun gear, and the performance of the other structural solutions is not as good as the above two solutions 131 - From the above analysis, when the vehicle is at a low speed or a high speed, there is an electric power cycle inside the composite power split system. Therefore, the system efficiency at low vehicle speed is optimized by adding a brake B1 on the planetary carrier, that is, at low vehicle speed, the engine is locked by closing the brake B1 through corresponding control, so that it is in a stopped state, and the whole vehicle runs in pure electric mode. A brake B2 is added on the shaft of the motor E1 to optimize the system efficiency at higher speeds, that is, at a higher speed, the corresponding control is applied to close the brake B2 to lock the motor E1. The engine directly drives the inner motor, and by adjusting the torque of the inner motor, the engine speed is closed loop controlled so that the engine always works at the best fuel consumption point.

As the electromagnetic makes the inner rotor rotate to generate electricity, the electromagnetic torque of the interaction between the inner and outer rotors will drag the outer rotor to rotate in the same direction as the inner rotor, but at different speeds. Under the control of the inverter, the inner motor makes the inner the torque of the motor and the power corresponding to the difference in the speed of the two rotors are transmitted in the form of electric energy to the high-voltage bus. The power corresponding to the torque of the inner motor and the speed of the outer rotor is still output in the form of mechanical energy to directly drive the wheels. The motor has a low-speed large with the characteristics of torque, high speed and high power, the power assist performance of the electric motor can be fully exerted no matter it is a low-speed driving condition or a high-speed driving condition. The electric motor improves the dynamic performance of the vehicle in a short period of time and has little impact on the operation of the internal combustion engine. It is also possible to reduce the power reserve factor of the engine and use an engine with a slightly smaller displacement when selecting the engine type.

2. THE PROPOSED METHODOLOGY

2.1 Dual-mode power-split hybrid system operating mode

The use of electric motors to assist can not only improve the power performance of the vehicle, but also effectively reduce fuel consumption and emissions. When the vehicle speed and required power are less than the set value, the engine is turned off at this time, and the battery supplies power to the motor II, and the motor II drives the car to run purely electric, or to accelerate from the original place or climb a steep slope at a lower speed, part of the output of the engine The power is generated by the motor I, and supplies power to the motor II together with the battery, and the motor II and the engine together provide the torque required for in-situ acceleration or climbing. When judging the rationality of the calculation results of the dynamic torque basic function, the deductive induction method is used to replace the parameters beyond the boundary range with the boundary values of the constraints. Through this heuristic logical reasoning method, the torque can be controlled within each within the allowable range of component capabilities. In the case of moderate braking intensity, the combination of mechanical brake and electric motor brake is used to realize vehicle braking, so that part of the vehicle kinetic energy is converted into electric energy and stored in the battery through the electric motor.

This mode of operation not only reduces brake usage, increases energy recovery, but also prolongs brake life and reduces brake requirements. The vehicle simulation program of the forward simulation method includes a driver model, which considers the demand speed and current speed, to generate throttle and brake commands (usually using a PI controller). The throttle command is converted into engine (and, or electric motor) torque and energy utilization, where the torque generated by the engine is sent to the gearbox model, and then the converted torque is calculated according to the efficiency and gear ratio, which is then calculated according to the actual power flow in the vehicle direction forward. until the driving force of the tire is calculated.

In this Hamiltonian function, the first half of the function is the instantaneous fuel consumption of the engine, the second half is the equivalent instantaneous fuel consumption corresponding to the increase or decrease of power battery power, and the sum of the two parts is the minimum equivalent fuel consumption in real time Optimizing the objective function of an energy management control strategy. By solving the minimum value of the current instantaneous Hamiltonian function, the control variable nVm(t) corresponding to the minimum value is obtained. The principle of determining the operation mode of the whole vehicle is according to the behavior of the driver, take the driver's demand as the starting point. At the same time, regardless of the specific work of each component, control instructions are sent to each component according to the needs of vehicle control.

2.2 Research on control strategy optimization of dual-mode power-split hybrid electric vehicle driving conditions

When the vehicle is running with low battery power or load, to ensure the normal driving performance of the car or maintain the engine working in a high-efficiency area, the electric motor works in power generation mode to maintain the battery power level or increase the engine load to make it Work in the high-efficiency zone, thereby improving energy utilization as a whole. At this time, both clutches C1 and C2 are engaged, that is, when the vehicle speed is lower than 35km/h, the required power is less than 10kw and the SOC of the battery is higher than 0.5, the battery supplies power to the motor U to drive the car, which is in a pure electric working condition; When the battery is lower than 0.5, no matter how low the vehicle speed is at this time, the engine will start; in the acceleration condition, the motor II and the engine drive the vehicle together; in the deceleration braking, the motor II performs energy recovery. In the whole cycle condition, the sum of the torque of the engine and the motor II always meets the requirement of the required torque.

The comparison between the fuel consumption per 100 kilometers and the traditional prototype car (engine displacement 1.8L) is shown in the table below. Compared with the original strategy, under the control of the ECMS algorithm control strategy, most of them operate in pure electric mode under the NEDC urban driving cycle, and only start the engine when the SOC is low, to avoid the engine working under the condition of low power demand of the whole vehicle , thereby reducing the actual fuel consumption of the engine. In suburban working conditions, the engine power basically meets the driving power of the vehicle, and the power battery provides power assist at low and medium speeds, and charges and recovers energy at high speeds. During the research and development of hybrid electric vehicles, static, quasi-static and dynamic analysis are all based on simulation models.

To verify the control mode and strategy of hybrid electric vehicles, and analyze the power performance, fuel economy performance and emission performance of the whole vehicle at the same time, this paper established a simulation platform based on Matlab/Simulink for the target vehicle equipped with the electromagnetic power split hybrid powertrain system. The power of the engine is designed according to the requirements of the stable maximum speed, and when the hybrid electric vehicle is running at a stable maximum speed, the electric motor is not considered to participate in the work, so the hybrid power transmission system still uses the engine of the prototype vehicle. ADVISOR2002 is a simulation software developed by the American Renewable Energy Laboratory under the software environment of Matlab and Simulink. It is currently the electric vehicle simulation software with the largest number of users in the world.

At present, many enterprises and research institutions in the world use this software as a simulation tool to carry out research work, and there are many successful application examples. And the power components in the system were selected, and the forward simulation model of the whole vehicle was established; the required torque of the whole vehicle was defined; according to the working state of the whole vehicle, the mathematical model of the system was decoupled to obtain the solution of the dynamic torque coupling algorithm. Based on the decoupling algorithm of dynamic torque, the torque control strategy of the whole vehicle is designed by deduction and induction, according to the optimized engine model and the oil-to-electricity conversion coefficient calculated by simulation, the equivalent fuel consumption based on the minimum principle is designed. Minimal energy management control strategy. The fuel economy of the engine is relatively good in the medium load and medium speed range, so it is considered that it is more economical to use the pure electric motor drive mode in the case of light load and low speed.

The simulation process of ADVISOR is to calculate the backward path first, and then calculate the forward path. In the backward path, the road cycle module provides the driving trajectory of the car, so the vehicle module uses the vehicle driving force calculation formula to calculate the driving force, and converts it into the torque and speed of the requested wheel in the wheel module, and then delays to the path is transmitted to the upper module final drive, transmission, etc. step by step, until the requested power is distributed to the engine module and battery module according to the scheduling of the control strategy module.

3. CONCLUSION

Based on analyzing the system structure, working principle and determining the vehicle control mode, the control mode is verified based on the NEDC recycling vehicle simulation model, and the power and economy of the vehicle are analyzed. The results show that: the transmission control mode designed for the electromagnetic power split hybrid power system works normally under various working conditions, and the design and development of the transmission control mode for the electromagnetic power split hybrid power system focuses on the vehicle control mode and the whole vehicle The torque control mode in the control mode is analyzed. The comprehensive efficiency model of the hybrid system in charging and discharging conditions is established; the maximum comprehensive efficiency of the vehicle system is used as the optimization goal, and the optimal control strategy calculation model of the system is established, based on the efficiency models of the engine, motor I and motor II.

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