RESEARCH ARTICLE

Optimization and performance analysis of the power system in hybrid electric vehicles

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Abstract: Hybrid electric vehicles (HEV) are the most industrialized and marketable in electric vehicles. Referring to the basic structure and parameters adopted by PRIUS Hybrid of Toyota, this paper puts forward an optimization scheme of HEV. The parameters and type selection of power components are obtained according to the vehicle's dynamic formula. The optimized hybrid power system is built and simulated through the simulation platform AVL Cruise. Then the obtained economic and dynamic parameters are analyzed and compared with the original performance parameters, verifying that the optimized system has better performance.

Keywords: Vehicle; hybrid power; optimization; AVL Cruise

1. Introduction

Vehicles are indispensable means of transportation in people's daily life with an increasing ownership year by year. However, energy shortage and environmental pollution faced by the whole world bring pressure to the automobile industry and prompt its structural improvement. It is the future development trend to transform fuel-fired vehicles into new energy ones. Combining the advantages of traditional fuel-fired and pure electric vehicles, HEV have not only strong power performance, but also low fuel consumption and emissions. Research on HEV can effectively solve the contradiction between the increase of car ownership and the energy and environment crisis.

Taking PRIUS Hybrid of Toyota as a model, this paper introduces the power supply by the engine power system and the electric power system under different modes, expounds the basic structure and parameter scheme adopted by PRIUS, compares its powertrain system and performance index, and puts forward various optimization schemes of HEV power system and their parameters. Through calculating the vehicle's dynamic formula, the matching parameter values of the main components of power system for tandem HEV are determined. With the aid of AVL Cruise, the structure of the optimized HEV is built and simulated, obtaining the maximum speed, maximum grade-ability, acceleration time and comprehensive fuel consumption. The comparison of various performance parameters verifies improvement of the dynamic and economic performance of the model, and provides a theoretical reference for research of HEV power system. 2. Research and analysis of HEV power system

PRIUS of Toyota is the world's first mass-produced hybrid vehicle, which is internally equipped with a hybrid of an engine and an electric motor. The present new PRIUS developed in our country adopts Toyota's 2nd generation hybrid system (THS II). The system includes engine, battery, driving motor, motor/engine and planetary gear mechanism. Variable speed is achieved by planetary gear mechanism, with no need for a transmission in the system. The engine is connected to the sun gear, which drives the planet carrier to rotate in the same direction. In the actual operation process, the rotation speed of the planet gear is directly affected by the vehicle speed, and kept within the optimal efficiency range by controlling the rotation speed of the generator. Different parameters of components will dir-

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ectly impact the vehicle's power, fuel economy and emission performance. For the system structure, the selected parameters should fully meet the performance index of the vehicle.

3. Optimization and analysis of HEV power system model

There are three modes of HEV, in which the tandem structure is the simplest. The overall structure is a pure electric vehicle added with a gasoline generator, realizing oil-electricity hybrid. It is a good way to transit to a pure electric vehicle at present, not only making up for the continuous driving capability of pure electric vehicles, but also becoming more flexible and simpler in the structural arrangement because of eliminating the ordinary gearbox. The engine always works in the high-efficiency rotating area. When driving at medium and low speeds, the tandem HEV has lower fuel consumption than ordinary vehicles, saving about 30% of the fuel. At the same time, the electric driving mode in tandem HEV eases users' operation. This paper proposes the tandem hybrid power for optimization. In order to better improve the power and economy performance of vehicles, the main components of the power system need to be selected and matched. The choice of lithium battery mainly depends on the voltage and capacity. The voltage should be the same as or slightly higher than that of the motor. The capacity should be selected according to the motor.

4. Performance simulation of HEV

4.1 Establishment of HEV simulation model

The calculation of the total power of HEV is relatively complicated, mainly composed of the power output of the engine and the motor. The types and characteristics of working power sources vary from different road conditions and driving modes. On the basis of the analysis of the dynamic model of the whole vehicle and combined with the vehicle's dynamic formula, the speed of the vehicle mainly depends on the driving force of the power source and the resistance in the driving process. According to the respective characteristics of the engine and the motor, it is clear that there is a very significant functional relationship among the driving force, the rotational speed and torque.

4.2 Analysis on simulation results of HEV

In the actual starting process, the vehicle can reach the required cruising speed through full acceleration from the initial standstill to the final stable running state. After a period of time, the maximum speed the vehicle can reach is 178 km/h. At the beginning, the vehicle is at a low speed, with relatively large torque and strong grade-ability. However, as the vehicle speed gradually increases, the torque will gradually decrease as well as its grade-ability. The maximum grade-ability of a vehicle is 35.35%. The acceleration time of HEV is simulated through AVL Cruise. The acceleration time under speed of 0-100 km/h is 6.7 s. The shorter the acceleration time is, the better the vehicle's dynamic performance. The importance of acceleration is manifested specially in emergency situations, such as at the intersection starts and overtaking on the highway.

Through optimizing PRIUS power system of Toyota, the maximum vehicle speed was raised from 160 to 178 km/h; the maximum grade-ability was increased from 17.9% to 35.35%; the acceleration time under speed of 0-100 km/h is shortened from 9.66 to 6.7 s; the comprehensive fuel consumption was reduced from 4.7 to 3.85 L. By comparing economy and power performance with that of the original power system, the optimized HEV has greatly improved. It also verified that the hybrid system and design parameters proposed in the design process were feasible.

5. Conclusion

(1) Taking PRIUS of Toyota as the research object, this paper obtains the structure that adopts planetary gear mechanism to achieve variable speed, lists the main parameters of the components of the whole vehicle and its performance index.

(2) The optimal structure of hybrid power system is proposed, which adopts the tandem hybrid power structure. According to the normal driving requirements of the vehicles, the main components of the power system are selected and parameters matched, thus determining their specific parameters.

(3) The dynamic model is built and simulated with AVL Cruise. The maximum speed of the vehicle is 178 km/h; the maximum grade-ability is 35.35%; the acceleration time under the speed of 0-100 km/h is 6.7 s, and the comprehensive fuel consumption is reduced from 4.7 to 3.85 L. The comparison and analysis with the original performance indexes of the power system prove that the designed HEV has better power and economy performance, achieves the optimization purpose and verifies its feasibility.

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