Running costs evaluation of the fuel cell hybrid powertrain using $Li_4Ti_5O_{12}$ battery

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As a promising power source for the renewable energy vehicle, fuel cell(FC) obtains intensive focus by researchers from all over the world. However, the fuel cell is deficient to suffer heavy variable load. Thus it must be hybridized with an auxiliary power unit. One of the common auxiliary units is the Li-ion battery, and a typical series hybrid structure is shown in Fig. 1[1].

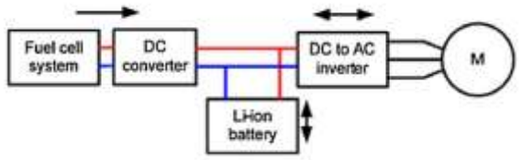

Figure 1 Hybrid structure of the fuel cell powertrain

Since 2000, a new type of Li-ion battery with $LiTi_5O_{12}$ anode has been developed. The lithium titanate battery also employs lithium cobalt, lithium manganese oxide or lithium iron phosphate as its cathode. The difference between the lithium titanate battery and the ordinary lithium ion battery is the anode material. To be brief in this paper, we call the battery with $LiTi_5O_{12}$ anode the LTO battery, and call the battery with graphite anode the LC battery. A prominent property of the LTO battery is its longevity. It is announced by Toshiba Co. Ltd. that their LTO battery named SCiB can endure more than 5000 cycles or more. Another extraordinary property of the LTO battery is its capability of high current discharging[2-5]. Owing the two advantages, the LTO battery is regarded as a promising choice for hybrid use.

However, how much will it cost if we substitute the LC battery by LTO battery in the fuel cell hybrid powertrain? When we are doing structure selection, the battery cost may be higher by utilizing LTO, however, the fuel cell rated power can be reduced and the life time of the fuel cell can be extended. In this paper, we proposed a dynamic model to evaluate the life cycle cost of fuel cell powertrain. First, we calculate the product cost of both the LTO and the LC battery. Second, we describe the assumptions of the cost evaluation model, reserved value is proposed for calculation. Third, we do simulations on the dynamic cost evaluation for different powertrain structure under specific control strategies. And then by analyzing the model results, we find that the FC+LTO structure of powertrain may be a better choice than that of FC+LC.

In this study, a dynamic cost model is established to evaluate the feasibility to utilized the battery with lithium titanate anode to substitute the battery with graphite anode in a hybrid fuel cell powertrain.

Load variation shortens the lifetime of the fuel cell. The transient load should be absorbed by the power battery. A new kind of battery using $Li_4Ti_5O_{12}$ as anode can absorb the most. Due to its good performance of high rate charging and discharging, the LTO battery absorbs more variable load, so that the FC can work at a more stable condition, and the maximum power of the FC can be reduced to save money. However, since the LTO battery costs more, will it be a better choice? In this paper, dynamic cost evaluation models for the fuel cell hybrid powertrain is established. Comparisons are made between the powertrain structures of FC+LTO and FC+LC.

However, the cost of LTO battery is still high due to high cost of the anode material. By calculation, the cost of commercial LTO battery is about 3 times than that of the LC battery. Nevertheless, since the rated power for the FC can be reduced for the high power output capability of the LTO battery. So the FC costs in FC+LTO structure is less than that used in FC+LC structure. And the total cost of the FC and the battery can be almost the same.

The FC+LC hybrid structure and the FC+LTO structure are proposed for cost analyzing. And different power management strategies influence the life time of the FC. The performance of the powertrain degrades during working. Considering the longevity of the FC and the battery, a reserved value model is established to compare the dynamic cost loss of the two structures. In addition, the FC+LTO structure can utilize constant power management strategy to extend the life time of the FC.

Reserved value is proposed to evaluate the life degradation of the fuel cell and the battery during road running. We propose possible dynamics by empirical formula to calculate the real-time life degradation of both the FC and the battery. Then the life degradation are transformed to reserved value.

Simulation results of the reserved value show that by using LTO battery, the reserved value loss is proportionally reduced, the lifetime of the fuel cell hybrid powertrain extends to about 2 times than that of the original one.

In conclusion, we have researched the feasibility of utilizing the LTO battery to substitute the traditionary Li-ion battery as an auxiliary power unit for the hybrid fuel cell powertrain. By results simulated from our dynamic model, the LTO battery may be a promising substitute used in the fuel cell hybrid powertrain, if well designed in hybrid structure and properly managed by power control strategy.

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