International Journal of Automotive Technology (2024) 25:107–117
https://doi.org/10.1007/s12239-024-00017-7

ELECTRIC, FUEL CELL, AND HYBRID VEHICLE, ELECTRICAL AND ELECTRONICS

Design and Application of Flywheel–Lithium Battery Composite Energy System for Electric Vehicles

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Received: 16 March 2023 / Revised: 7 September 2023 / Accepted: 10 October 2023 / Published online: 12 February 2024

Abstract
For different types of electric vehicles, improving the efficiency of on-board energy utilization to extend the range of vehicle is essential. Aiming at the efficiency reduction of lithium battery system caused by large current fluctuations due to sudden load change of vehicle, this paper investigates a composite energy system of flywheel–lithium battery. First, according to the design requirements of vehicle performance, the essential parameters of the hybrid energy storage system are designed using CPE function. Then, based on the vehicle dynamics and operating principle of the hybrid energy system, a mathematical model for performance analysis of the hybrid energy electric vehicle is established. Finally, energy management strategy for the hybrid energy system is designed with the use of wavelet algorithm. Research results show significant improvement of the storage system efficiency. Specially, compared with the original scheme, owing to the flywheel battery, the maximum current and discharge rate of the lithium battery are reduced by 6.55% and 4.76% under WLTC working condition. Meanwhile, the average current is decreased by 14.93%. Furthermore, the average efficiency of lithium battery is improved by 3.07%. The overall efficiency of energy storage system is increased by 2.01%.

Keywords Electric vehicle · Flywheel battery · Composite energy system · Energy management

Abbreviations

E_{bat}	Energy storage of lithium battery pack
E_{rep}	Energy required to meet the driving range
P_{rep}	Power required by vehicle
C_{bat_cell}	Capacity of single cell
U_{bat_cell}	Voltage of single cell
N_{bat_s}	Number of battery pack branches in series
N_{bat_p}	Number of battery pack branches in parallel
η_{DOD}	Depth of discharge
m	Mass of vehicle
g	Acceleration of gravity
f	Rolling resistance coefficient
C_D	Air resistance coefficient
A	Windward area of vehicle
v	Vehicle speed
P_{max}	Drive motor peak power
P_{cell}	Maximum output power of a single battery
η_m	Motor efficiency
C	Maximum discharge rate
P_{bat}	Output power of lithium battery
P_{fb}	Output power of flywheel
P_{rep_max}	Peak power of vehicle
P_{bat_max}	Peak power of lithium battery
P_{fb_max}	Peak power of the flywheel battery
P_{bat_limit}	Lithium battery output power threshold
$\mathrm{F_i}(P_{bat\_limit})$	Maximum the CPE value of the whole trip
E_{fb_max}	Energy capacity of flywheel
j	Rotational inertia of flywheel rotor
ωmax	Peak speed of flywheel
λ	Depth of discharge of flywheel battery
η_{fb_ave}	Average efficiency of flywheel battery
F_t	Driving force of vehicle
F_f	Rolling resistance
F_w	Air resistance
F_j	Acceleration resistance
F_i	Ramp resistance
T_{tq}	Drive motor torque
i_g	Transmission ratio
i_0	Main gear ratio
η_t	Driveline efficiency
r	Wheel radius
α	Road ramp angle
δ	Rotating mass conversion factor

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