Evaluating supercapacitors to improve electric motorcycles

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Introduction

Motorcycles are currently lagging cars in adopting electric power. Currently few of the main manufacturers offer an electric option, despite bans on sales of new ICE vehicles being implemented from 2035.

Supercapacitors (SCs) may be a good option for motorcycles, which are typically more limited in terms of weight increase and thus battery capacity than electric cars with current lithium-ion batteries. The main aim of this project was to assess the feasibility of implementing supercapacitors into electric-powered motorcycles to improve power output, reduce battery degradation, cost, charge time and reduce mass.

Methodology

- A literature review was conducted to identify areas of interest. Power output, maximising battery efficiency, reducing battery degradation, charge time and reducing mass were investigated
- The specifications for seven popular electric motorcycle models were used for comparisons. Relevant data used included battery capacities, mass and power output
- Specifications for seven supercapacitors were used for analysis, from multiple market leaders. Data used included capacitance, specific energy and cost per cell
- Average figures for key metrics such power density, cost/kg and specific capacitance were calculated from the supercapacitor specifications to enable further calculations
- Formulae used included but were not limited to:

Maximum Stored Energy

$$E_{max} = \frac{\frac{1}{2}CV^2}{3{,}600}$$

Charge Time

$$t = \frac{C(V_s - V_e)}{I}$$

Gravimetric Specific Energy

$$(E_s) = \frac{E_{max}}{M}$$

Charge Current

$$I = \frac{SC\ P_d \times m}{V_R}$$

Maximum Usable Specific Power

$$P_d = \frac{0.12 \times V^2}{ESR \times m}$$

Discussion

- Results showed that supercapacitors could increase peak power at potentially minimal cost and mass gain, or allow for a lighter battery while maintaining the same power (at a cost to range relative to the battery mass removed)
- Supercapacitors can be used for current levelling, decreasing battery wear and extending life
- Limited energy density of supercapacitors is the main limitation of the technology; modest power increase of up to 9% sustained for 30 seconds might be possible with the quantity analysed (up to 2.5% of total mass for each model)
- Further work could include modelling of the system to verify the results shown below, and later a prototype to test the performance and develop an integrated solution

Supercapacitors can:

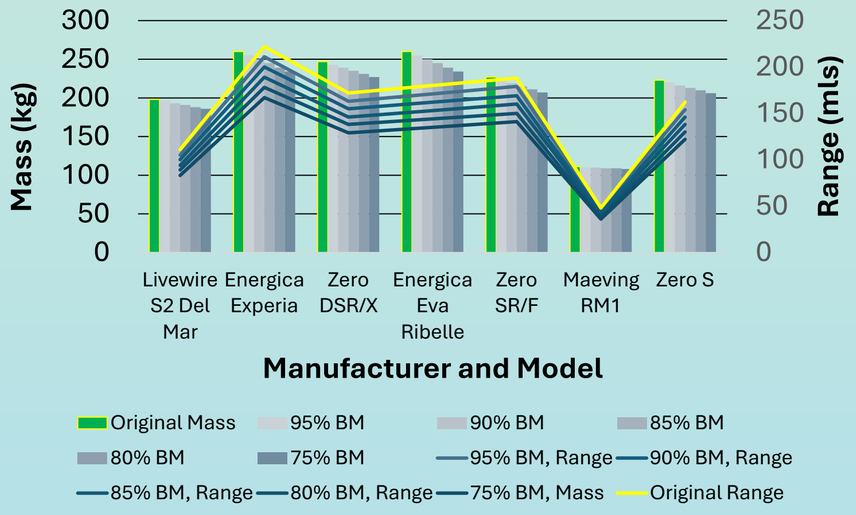
Extend Battery Lifetime

- Battery lifetime can be improved with SCs by limiting current and discharge cycles

Reduce Mass While Maintaining Power:

- Using SCs to maintain peak power while reducing battery mass is achieved with a low mass of SCs – less than 5kg for a 25% reduction in battery mass. The biggest downside is range reduction.

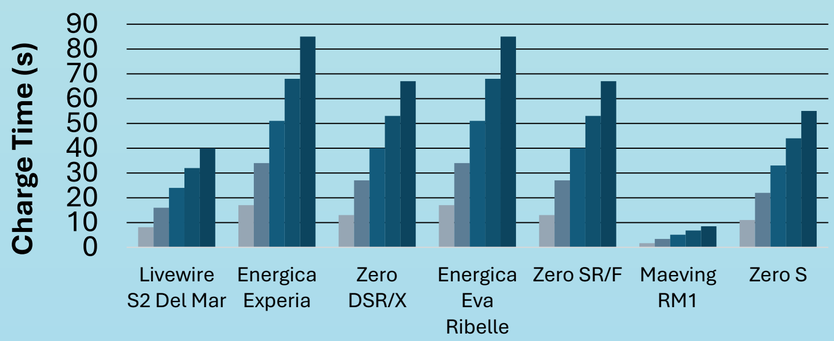
Total Mass and Range Reduction, 100 - 75% Battery Mass



Recharge in Under 1 minutes 30 Seconds

- Discharge time at peak power is under 5 seconds, while charge time is limited by infrastructure, at just over 13s/kg, resulting in a maximum theoretical charge time in the results of 85 seconds.

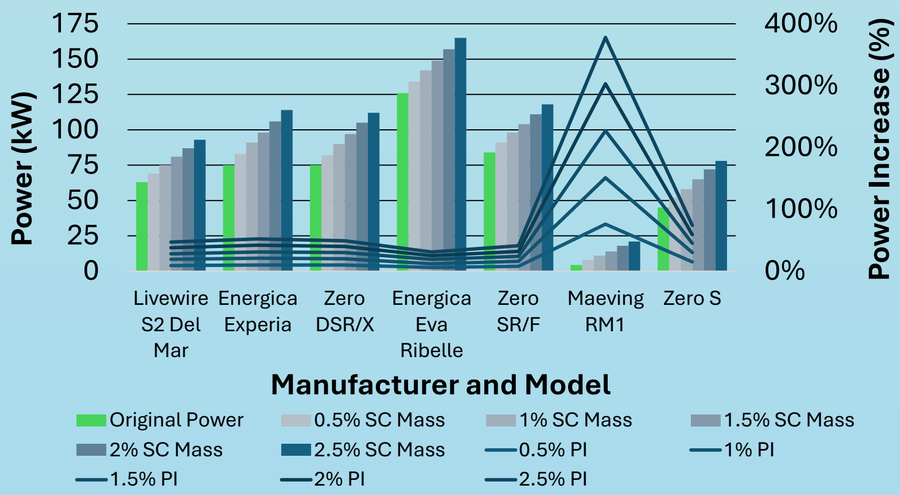
Charge Time of SC Module, Based on Relative Mass



Improve Peak Power:

- SCs can be added to the standard battery size to significantly improve peak power – at least 30% increase may be possible with an SC pack equivalent to 2.5% of vehicle mass.

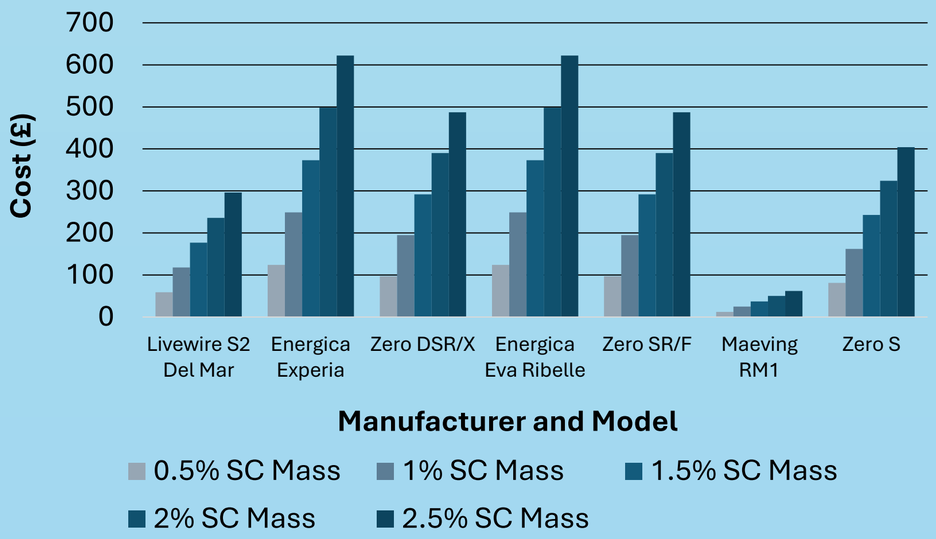
Power Increase After SC Module Added, Based on Relative Mass



Improve Power at Low Cost

- Costs of the SCs by mass ranged from £12 to £622, or £150/kg. This did not include cost of implementing or motor upgrades.

Cost of SC Module, Based on Relative Mass



Provide Sustained Power Increase

- Modest increases to peak power can be achieved with a lower discharge current

30 Second Sustained Power, Percentage of Peak Power