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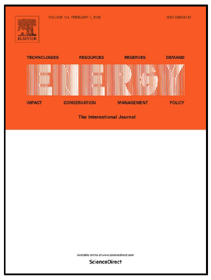


Analysis of Road Curvature's Effects on Electric Motorcycle Energy Consumption

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# Analysis of Road Curvature's Effects on Electric Motorcycle Energy Consumption

Alireza Farzaneh, Ebrahim Farjah

***Abstract*—Concerns over carbon emissions have motivated motorcycle producers to explore the use of electric energy instead of gasoline. Due to battery capacity limitations, electric energy consumption should be optimized to extend the range of Electric Motorcycles (EMCs). Road curvature is an inevitable part of motorcycle travel, and this paper proposes a detailed electric motorcycle model to calculate electric energy consumption on both straight curved roads. Simulation results show that road curvature has a significant effect on energy consumption, so a Dynamic Programming (DP) optimization strategy was used to calculate EMC optimized speed over curved roads**

***Index Terms— Electric Motorcycle, Energy Consumption Optimization, Road Curve, Range, Dynamic Programming.***

## I. Nomenclature

| | |
|---|---|
| $N_r$ | Load on Rear Wheel |
| $N_f$ | Load on Front Wheel |
| $\alpha$ | Road Grading Angle |
| m | Mass (sum of battery, driver and motorcycle mass) |
| G | Gear Ratio |
| $\rho$ | Air Density |
| $C_D$ | Aerodynamic Coefficient |
| $C_L$ | Lifting Coefficient |
| A | Frontal Area |
| a | Motorcycle Acceleration |
| $R_o$ | Tire Radius |
| $i_g$ | Gear Ratio |
| $\eta_g$ | Gear Efficiency |
| $\eta_m$ | Electric Motor Efficiency |
| $\varphi$ | Roll Angle |
| $R_c$ | Curve Radius |
| t | Tire Cross Section Radius |
| V | Motorcycle Linear Speed |
| $\Omega$ | Motorcycle Angular Speed |
| $\varepsilon$ | Caster Angle |
| $\Delta$ | Kinematic Steering Angle |
| $\delta$ | Steering Angle |
| $F_a$ | Acceleration Force |
| $F_r$ | Rolling Resistance Force |
| $F_{ad}$ | Aerodynamic Drag Force |
| $F_g$ | Grading Resistance Force |
| $F_{Ld}$ | Lifting Force |
| $\omega_m$ | Electric Motor Angular Speed |
| $\omega_t$ | Tire Angular Speed |
| $\lambda_f$ | Front Wheel Slide Slip |
| $\lambda_r$ | Rear Wheel Slide Slip |

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## II. Introduction

Although technological advancement makes human life more comfortable, it often causes damage to the environment. Greenhouse gas (GHG) emissions are the most serious problem stemming from technology, most of which are caused by Internal Combustion Engine (ICE) vehicles [1]; 33.7% of GHGs are emitted by transportation systems, despite only consuming 27% of environmental energy.

Motorcycles make a significant contribution to these emissions. Many motorcycles are manufactured without Engine Control Systems (ECS) and catalytic converters; combined with a high energy consumption to weight ratio and poorly-optimized ICE operations, this results in motorcycles serving as the main cause of environmental pollution and GHG emissions in many overcrowded urban areas [3]. Thus, the use of electricity as a clean, high-performance, and zero-emission energy source in motorcycle propulsion systems is an important step to reduce air pollution. Convenient controllability, higher torque (improving motorcycle stability and safety), and fuel cost reduction to 2 cents per mile are some advantages of superseded electric propulsion systems in motorcycles. [2, 4]

Due to the fact that battery capacity limitations reduce Electric vehicles (EVs) range, various energy management methods have been introduced to optimize EV energy consumption. As road conditions affect the dynamic behavior and energy consumption of electric vehicles, most of the proposed optimization techniques are based on standard speed profiles, which are introduced in [5].

Reference [6] introduces two-level optimization problems to extend EV range in cruise mode and reduce traveling time. A simple speed profile on straight roads, containing one acceleration and one breaking mode, is used to evaluate results. The two-level energy management strategy introduced in [7] and standard speed profiles (NEDC[1], ARTEMIS[2] URBAN and Motor way cycle) are used for simulation purposes. Speed profiles ECE[3]15 and ARTEMIS are used in [8] for multilevel energy management in multisource EVs.

[1] New European Driving Cycle
[2] Assessment and Reliability of Transport Emission Models and Inventory Systems
[3] Economic Commission for Europe