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МОДЕЛЬ ДЛЯ РАСЧЕТА ПОТРЕБЛЯЕМОЙ ЭНЕРГИЕЙ МОТОЦИКЛОВ С УЧЕТОМ РЕГИОНАЛЬНЫХ ОСОБЕННОСТЕЙ ДОРОЖНОГО ДВИЖЕНИЯ

A REGIONAL TRAFFIC CHARACTERISTIC BASED MODEL FOR MOTORCYCLE ENERGY CONSUMPTION

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Моделирование энергопотребления мотоциклов привлекает значительное внимание исследователей благодаря его важной роли в проектировании двухколесных транспортных средств, оценке их эксплуатационных характеристик, охране окружающей среды и разработке интеллектуальных систем. В данной работе представлена модель для расчета потребляемой энергией мотоциклов, учитывающая региональные особенности дорожного движения. Модель разработана как для мотоциклов с двигателем внутреннего сгорания, так и для электрических мотоциклов. Адекватность разработанной модели определяется путем сравнения рассчитанного энергопотребления с данными, предоставленными производителями *при движении в стандартном ездовом цикле WMTC для двух моделей: Honda Icon e и Honda Vision. Полученные результаты демонстрируют отклонения менее 10 %, что подтверждает высокую точность предложенной модели.*

Energy consumption modeling for motorcycles has been extensively studied due to its importance in two-wheeled vehicle design, performance evaluation, environmental protection, and intelligent system development. This paper proposes an energy consumption model for motorcycles that incorporates regional traffic characteristic parameters. The model is developed for both internal combustion engine motorcycles and electric motorcycles. Validation is performed by comparing the model's calculated energy consumption with manufacturer-reported data under the WMTC standard driving cycle for two vehicle models: Honda Icon e and Honda Vision. Results show deviations of less than 10 %, confirming the model's accuracy.

Ключевые слова: *моделирование, потребляемая энергия мотоцикла, электрический мотоцикл, характерные параметры регионального дорожного движения.*

Keywords*: modeling, motorcycle energy consumption, electric motorcycle, regional traffic characteristic parameters.*

INTRODUCTION

Vietnam stands out as one of the most motorcycle-dependent countries in the world. According to the International Council on Clean Transportation (ICCT), Vietnam ranks second globally in terms of the number of motorcycles, just after India, despite having a significantly smaller population [1]. In fact, the motorcycle ownership rate in Vietnam is among the highest in the world, with over 70 million units in circulation as of recent years [2]. This density is evident in Hanoi, where motorcycles dominate the streets, accounting for the majority of daily commutes.

The widespread use of ICE motorcycles in Hanoi contributes substantially to urban air pollution and greenhouse gas emissions [3]. Recognizing these environmental concerns, the Hanoi municipal government has proposed a ban on gasoline-powered motorcycles by 2030, aiming to improve air quality and promote cleaner modes of transportation [4]. This planned transition toward electrification creates an urgent need for robust and region-specific vehicle energy consumption models to assess energy consumption and environmental impact.

While energy consumption models have been developed for various vehicle types – such as passenger cars, vans, trucks, and buses-comparable models for motorcycles remain lacking [5]. Existing motorcycle energy consumption models often rely on standardized cycles or real-time measurements, which are time-consuming, experimentally demanding, and poorly reflect local traffic conditions [6–8]. As a result, these models may yield inaccurate fuel and energy estimates, reducing their effectiveness for policy analysis and urban planning.

This study addresses these gaps by developing and validating an energy consumption model for motorcycles that integrates regional traffic characteristic parameters (RTCPs). The model is applicable to both electric and ICE motorcycles and is verified against real-world performance data under the WMTC driving cycle.

1. MOTORCYCLE ENERGY CONSUMPTION MODEL

1.1 Assumptions.

The model is built based on the following assumptions:

– for each completed driving cycle, the vehicle's velocity and position at the start and end are the same. Therefore, the negative inertia equals the positive inertia, and the braking power can be considered positive based on the vehicle's inertia;

– the vehicle moves on a road surface with good traction, in an environment without natural wind;

– neglect the additional losses caused by turning, as the time spent turning and steering is minimal compared to the total duration of the driving cycle;

– rapid acceleration or hard braking can cause wheel slip, affecting energy consumption calculations. However, since such events are rare on high-traction roads and occupy an insignificant portion of the overall journey time, wheel slip can be neglected in this model.

1.2. Regional traffic characteristic parameters (RTCP).

This study adopts three characteristic parameters proposed by [9] to quantify driving behavior, vehicle speed, acceleration, and energy consumption per trip within a defined area. Their definitions and calculation formulas are summarized in tab. 1.

1.3. Motorcycle model for fuel/energy consumption calculation.

The model was developed regarding (Le Van Nghia, Dam Hoang Phuc, Duong Ngoc Khanh, Trinh Minh Hoang, Ho Huu Hai, 2022; Le Van

Nghia, Le Hue Tai Minh, Dam Hoang Phuc, Duong Ngoc Khanh, Bui The Dat, 2023), but was adjusted to suit motorcycles, as shown in fig. 1.

Table 1 – Regional traffic characteristic parameters (Simpson, 2005)

Parameter	**Formula**	**Characteristic features**	**Energy correlation**
Average velocity	$v_{avg} = \frac{1}{T} \cdot \int_0^T v \cdot dt$	The rate at which the vehicle completes the journey	Rolling resistance
Root-mean-cubed velocity	$v_{rmc} = \sqrt[3]{\frac{1}{T} \int_0^T v^3 \cdot dt}$	The range of vehicle speed variation throughout the trip	Aerodynamic resistance
Characteristic acceleration	$\tilde{a} = \frac{1}{2} . \frac{\Sigma(v_{final}{}^2 - v_{initial}{}^2)}{v_{avg} \cdot T}$	Quantitative assessment of speed variation over the course of the journey	Vehicle inertia

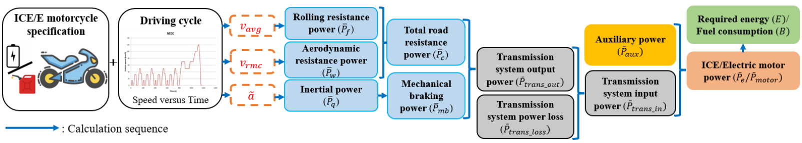

Figure 1 – Modeling sequence for ICE/Electric motorcycle

The model is derived from the wheel power balance equation, comprising resistance power (rolling and aerodynamic resistance) and inertial power. The average total resistance power is calculated as follows:

$$\bar{P}_c = \bar{P}_f + \bar{P}_w = m \cdot g \cdot \psi \cdot v_{avg} + \frac{1}{2} \cdot \rho \cdot C_w \cdot A \cdot v_{rmc}^3 .$$

The inertial power is averaged as follows:

$$\bar{P}_q = m \cdot \delta_i \cdot v_{avg} \cdot \tilde{a} \, ,$$

where $\bar{P}_f$ – is the average rolling resistance power (W), $\bar{P}_w$ is the average aerodynamic resistance power (W), m is the total vehicle mass and a driving person (kg), g is the gravitational acceleration (9,81 m/s²), ψ is the rolling resistance coefficient, C_w is the aerodynamic resistance coefficient,

A is the vehicle's frontal area (m²), ρ is the air density (kg/m³), δ_i is the rotational inertia coefficient of the drivetrain.

During deceleration, vehicle inertia is counteracted by rolling resistance and aerodynamic drag. If inertia exceeds these forces, braking is required. The average mechanical braking power is thus calculated as:

$$\overline{P}_{mb} = -\frac{\int_0^T (P_q + P_c)\Big|_{(P_q+P_c<0),\ (v-v_{tr}<0)} dt}{T},$$

where: T is the total duration of the driving cycle (s), and v and v_{tr} are the current and previous step velocities, respectively (m/s).

The transmission system output must meet the combined demands of total resistance power and mechanical braking power:

$$\overline{P}_{trans\_out} = \overline{P}_c + \overline{P}_{mb}.$$

The transmission input power is averaged as follows:

$$\overline{P}_{trans\_in} = \overline{P}_{trans\_out} + \overline{P}_{trans\_loss} = \overline{P}_c + \overline{P}_{mb} + \frac{1-\eta_{trans}}{\eta_{trans}}\left(\overline{P}_c + \overline{P}_q\right),$$

where: $\overline{P}_{trans\_loss}$ is the average power loss in the transmission system, η_{trans} is the transmission system efficiency.

Accordingly, the required power of the ICE/electric motor can be:

$$\overline{P}_e = \overline{P}_{trans\_in} + \overline{P}_{aux} \quad \text{or} \quad \overline{P}_{motor} = \overline{P}_{trans\_in} + \overline{P}_{aux},$$

where $\overline{P}_{\text{aux}}$ – indicates the average auxiliary power consumption, estimated to be around 100 W. The energy required for the ICE/electric motorcycle to complete the driving cycle is determined as follows:

$$E = \frac{\overline{P}_e \cdot T}{\eta_e} \quad \text{or} \quad E = \frac{\overline{P}_{motor} \cdot T}{\eta_{motor}},$$

where: η_e – is the internal combustion engine efficiency; η_{motor} – is the motor efficiency.

The ICE motorcycle's fuel consumption is thus calculated as follows:

$$B = \frac{E}{3{,}6 \cdot 10^6 \cdot \lambda \cdot v_{avg} \cdot T},$$

where λ – is the conversion factor from gasoline (liters) to energy (kWh/l) (U.S. Department of Energy, Alternative Fuels Data Center, 2024).

2. MODEL VERIFICATION RESULTS

The model is validated by comparing its results with manufacturer data on energy/fuel consumption, using the Honda Icon e and Honda Vision as representative electric and combustion motorcycles. The Vision, representing the 100–150 cc class, is chosen for its prevalence in Vietnam (ITST, CIEM & VAMM, 2024), while the Icon e is selected for its technical similarity. Specifications are provided in tab. 2. WMTC cycle (fig. 2), is used for validation.

Table 2 – Honda Icon e and Honda Vision specifications

Vehicle specification	**Honda Icon e**	**Honda Vision**
Total vehicle weight (kg)	162 (Vietnam)	169 (Vietnam)
Aerodynamic resistance coefficient	0,65 (Yuji Araki, Kazuhiro Gotou, 2001)	0,7 (Yuji Araki, Kazuhiro Gotou, 2001)
Frontal area (m^2)	0,6 (Yuji Araki, Kazuhiro Gotou, 2001)	0,8 (Yuji Araki, Kazuhiro Gotou, 2001)
Air density (kg/m^3)	1,167 (Shelquist, 2023)	1,167 (Shelquist, 2023)
Coefficient accounting for rotational inertia of the transmission system	1,05 (Krishnamurty, 2024)	1,08 (Krishnamurty, 2024)
The conversion factor from gasoline volume to energy (kWh/l)	–	9 (U.S. Department of Energy, Alternative Fuels Data Center, 2024)

End of the table 2

Rolling resistance coefficient	0,02 (Cossalter, 2005)	0,02 (Cossalter, 2005)
Transmission system efficiency	0,88 (Vietnam)	0,88 (Vietnam)
Motor efficiency	0,95 (Vietnam)	–
ICE efficiency	–	0,3 (Vietnam)

The calculation results for the two selected vehicle models are presented in tab. 3.

Table 3 – Model calculation results

Calculated parameters	**Honda Icon e**	**Honda Vision**
Average rolling resistance power ($\overline{P}_f$)	206 W	219 W
Average aerodynamic resistance power ($\overline{P}_w$)	325 W	347 W
Average resistance power ($\overline{P}_c$)	531 W	566 W
Average mechanical braking power ($\overline{P}_{mb}$)	149 W	157 W
Average auxiliary power ($\overline{P}_{aux}$)	120 W	100 W
Average transmission output power ($\overline{P}_{trans\_out}$)	680 W	723 W
Average transmission loss power ($\overline{P}_{trans\_loss}$)	240 W	345 W
Average transmission input power ($\overline{P}_{trans\_in}$)	920 W	1067 W
Average ICE/motor power ($\overline{P}_e$ / $\overline{P}_{motor}$)	1040 W	1167 W
Energy consumption (E)	34,1 Wh/km	–
Energy consumption (provided by manufacturer)	36 Wh/km	–
Fuel consumption (B)	–	1.89 l/100 km
Fuel consumption (provided by manufacturer)	–	1.82 l/100 km
Deviation	5,3 %	3,7 %

The model shows less than 10 % deviation from manufacturer data [14, 15], confirming its accuracy.

CONCLUSION

An energy consumption model for motorcycles using regional traffic characteristic parameters was developed with an error margin below 10 % compared to manufacturer data. The model enables analysis of power distribution across individual components, providing a basis for optimizing their performance. It can be extended to assess the transition from internal combustion to electric motorcycles in specific regions, offering valuable data for energy policy planning.

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