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Study of a Novel Hybrid Powertrain System for Honda Wave 110cc Motorcycle with Rear Wheel Electric Motor

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Abstract:- *This study introduces the method to apply hybrid technology to two wheels motorcycle based on the platform of Honda Wave 110cc. The contents including: selection of hybrid configuration and electric motor, alternator and battery. This paper presents the design of the hybrid powertrain system and the control system between the two power sources from traditional engines and DC motors on motorcycles kind of Honda Wave 110cc. Then experimental investigation will be conducted to analyze and evaluate for the developed Hybrid system, to propose solutions to improve the efficiency of the hybrid transmission system on the motorcycle. The results show that plug – in hybrid structure without generator is the most feasible and effective choice to renovate a traditional motorcycle in traffic condition of Vietnamese cities. Performance characteristics of the plug – in hybrid motorcycle are as well as original one. Besides, fuel consumption of plug – in can be saved 12.800VND/47 km less than 64% original one. In addition, the results are shown that the study obtained a better fuel cost and reduce emissions.*

Keywords: *Hybrid powertrain system, Hybrid electric motorcycle, Honda Wave 110cc*

1. INTRODUCTION

Viet Nam is one of the fastest growing economies in Asia, recording an average annual growth in GDP of about 7.5 % over the last decade. In the process of industrialization and modernization Vietnam has been facing many challenges on the way towards sustainable development. One of the most serious environmental problems currently faced by Vietnam is air pollution. Industrial emissions, and increasing number of motor vehicles using fossil fuels are main causes of loss of air quality in urban areas. Overall exposures to particulates, CO, CO_2, SO_2 and NO_x exceed permissible levels at many urban locations such as Ho Chi Minh city, Ha Noi city, etc. Recently motorcycle population has grown rapidly in many urban areas of Asia. According to Vietnam Association Motorcycle Manufactures (VAMM), total of two-wheelers continue to grow in the national market reached nearly 3.3 million vehicles in 2017, increasing by 4.8% [1]. Governments and automakers in many countries have responded by allocating considerable economic resources to develop fuel efficient vehicle powertrain technologies [1,2]. Electric Vehicles (EVs) have the potential to reduce fossil fuel usage, are facing challenges in consumer acceptance due to range limitations, lack of charging stations, the high cost of batteries and poor battery performance [3-5]. Internal combustion engines are facing with lack of sustainable fossil fuels, engine emissions, and climate change.

According to an expert on transportation in Vietnam, Vietnam is regarded as a “global center of motorbikes”, with more than 45 million two-wheelers in a population of 94 millions, and one can imagine how much air pollution they cause. On average, motorbikes from the 2000s generate 416 percent more hydrocarbons, 3,220 percent more nitrogen oxides, and 8,065 percent more carbon monoxide than motor cars produced in the same decade.While 8,000 new bikes are still sold every day. So, to decrease the air pullutions by personal transportation, not only the government need to continue investing in more high-quality public transportation, step-by-step approach to ban motorbike in many urbanareas, but aso taking into account that we may to innovate the original one to hybrid power train system.

In recent years the automotive makers and research groups have proposed different hybrid electric vehicles (HEV) and electric vehicles (EV) to reduce engine emissions. Several hybrid scooter and motorcycle have been developed to overcome limitations of conventional internal combustion engine on two wheeler motorbike. These are possessed by parallel designs where electric motor and engine are connected to the wheels for independent driving or combination [6]. This is because the PHEVs offer significant greenhouse gas benefit and greatly reduce the fuel consumption [7,8]. The most significant technical barrier in deploying commercially viable plug-in hybrid electric two-wheeler is the energy storage systems.This paper describes the design of a novel hybrid power train system, applicable to most of manual

transmission of motorbike with rear wheel electric motor.

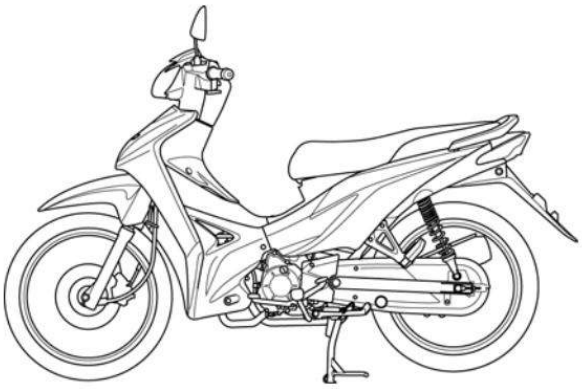


Fig -1: Side view of the Honda Wave 100cc Motorcycle

Table 1: Honda Wave 100cc Specifications

Specifications	*Contents*
Curb weight	97 kg
Overall length x width x height	1,914 mm x 688 mm x 1,075 mm
Wheel base	1,224 mm
Seat height	769 mm
Min-ground clearance	142 mm
Fuel tank capacity	3.7 l
Engine type	Gasoline, 04-stroke, single, air-cooled
Displacement	109.1 cm^3
Bore stroke	50 mm x 55,6 mm
Compression ratio	9.0 : 1
Max. output / rpm	6.12 kW/ 7,500 rpm (8 HP)
Max. torque / rpm	8.44 N.m/ 6,000 rpm
Gear box	Mechanical, 4-step rotary system
Starting system	Electric/kick starter

2. TECHNOLOGICAL SOLUTION OF HYBRID ELECTRIC POWERTRAIN

2.1 Pure powertrain system

A gearset of Honda Wave 100cc as show in figure 2 is propos. The motorcycle transmission delivers power to the rear wheel through a series of structures that include the gearset, the clutch and the drive system.

A gearset enable a rider to move from a complete stop to a cruising speed. The manual transmissions on motorcycles typically is 4-step rotary system. A clutch is to engage and disengage power from the engine crankshaft to the transmission.

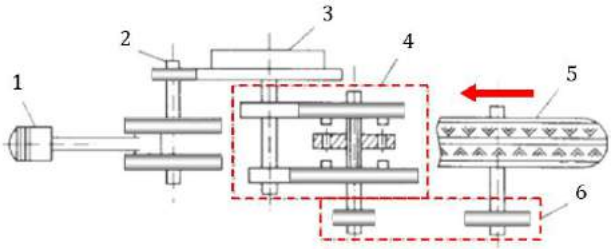


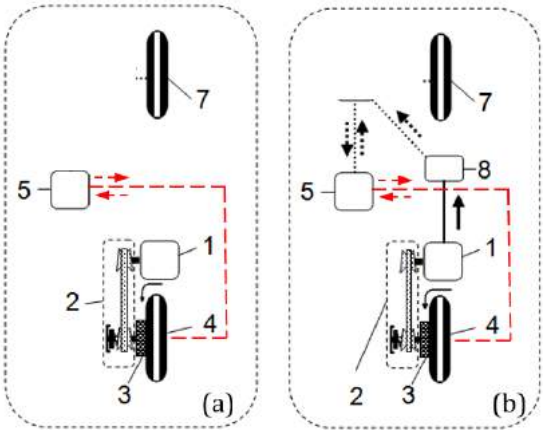
Fig-2: Schematic diagram of original powertrain configuration of Honda Wave 110cc
1 – piston; 2 – Crankshaft; 3- Clutch;
4 – Manual transmission; 5 – Rear wheel;
6 –Chain transmission

2.2 Hybrid powertrain systems (HPSs)

A hybrid vehicle uses at least two distinct types of power, such as internal combustion engine to drive an electric generator. That can run only on an internal combustion engine, only on an electric motor, or a combination of both. MEMs overcome some of the obstacles presented by original hehicles due to their potential advantage in terms of fuel efficiency and engine emissions [3]-[5].

This paper discusses the methodology for innovating hybrid electric motorcycle basing on pure internnal combustion engine motorcyle, Honda Wave 100cc, it is utmost popular in crowded city such as Ho Chi Minh.

For estimating the energy storage requirements and sizing of the battery pack, daily travel distance by a two-wheeler plays a vital factor. After reforming hybrid electric motorcycle (HEM), this paper discusses the energy consumption and cost analysis of HEM applying without generator configuration with Lithium Ion battery and rear wheel electric motor as shown in figure 3d.



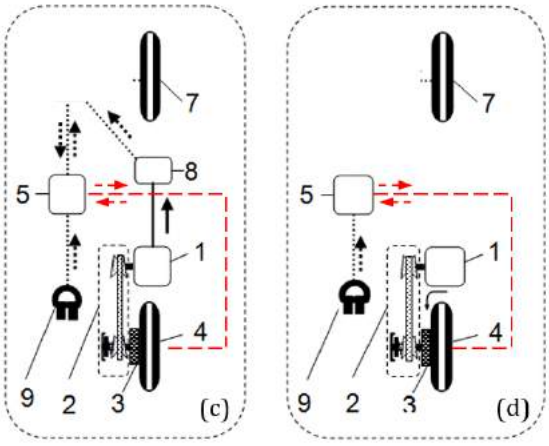


Fig-3: Schematic diagram of the power configuration (a) parallel, (b) series-parallel, (c) plug-in with generator, and (d) plug-in without generator

1 – Engine; 2 – Chain transmission;3 - Final drive;

4 - Rear wheel(BLDC motor); 5 – Battery;

7 – Front wheel;8 – Generator; 9 – Plug-in

2.3. Selection of Brushless DC Electric motor

The design concept assumed creation of an electric powertrain for a single-track vehicle, which would have a top speed on the level of 70 km/h and a range of about 50km. Basing on simple physics calculations, the preliminary calculations were made to estimate the necessary power output of electric motor:

$$Pc = \frac{V}{\eta_p}\left(m.g.fc + Cx.\frac{\rho.V^2}{2}.A\right), \qquad (1)$$

where:

m – motorcycle mass including rider and passenger (200kg),

g – Earth's gravitational acceleration, (9.81 m/s^2)

f_c – rolling friction coefficient (0,015),

C_x – drag coefficient (C_x = 0,65),

ρ – air density (1,2047 kg/m^3),

A – reference area (0,25 m^2),

V – assumed vehicle speed (60 km/h),

η_P – power transmission efficiency coefficient (0,98).

Fig-4: Schematic diagram of Hub motor 48V rear wheel 500W

Table 2: Technical Paramters of BLDC motor

Specifications	*Contents*
Rated Voltage	24/36/48V
Rated Power	350-500W
Wheel Size	18-28inch
Rated Speed	30km/h
Rated Efficiency	≥80
Noise	≤50db
Reduction ratio	1:5

When operating in propulsion mode, the motor provides propulsion torque to rear wheel and torque value can be calculated [9]:

$$T_m = T_{m\_demand} + T_{loss} + J_{mot}\frac{d\omega_m}{dt} \qquad (2)$$
$$where\ T_m < T_{m\_max}$$

Required electrical power and motor required current can be described by the equation [9]:

$$P_{elec} = \frac{P_m}{\eta_m}, i = \frac{P_{elec}}{U_{HV}} \qquad (3)$$

Where motor max torque T_{m_max} and lumped efficiency η_m are represented as lookup table of motor data maps.

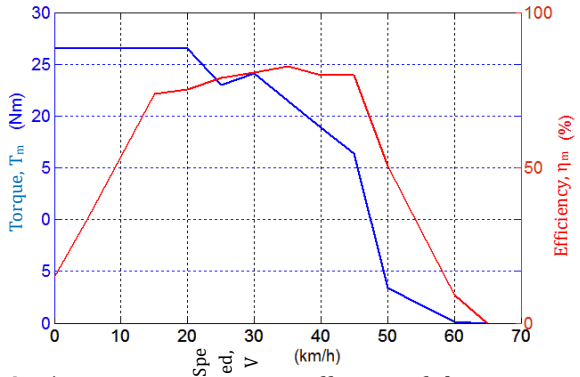


Fig-5: Torque vs maximum efficieny of electric motor

2.4. Lithium-ion battery

This paper presents a battery system consisting of 12 battery modules connected in series and each module includes 15 Lithium – ion battery cells connected parallel. The battery model is used to predict the state of charge and the current and voltage observed at battery terminals. Thestate of charge of the battery system can be calculated based on the battery ampere-hour capacity, current history, self-discharge, and charge/discharge efficiency... The parameters of the battery model are generally identified offline based on test data, such as the open – circuit voltage of each battery module U_{OC_i} is a function of SOC and temperature as shown in Fig. 6. [6]

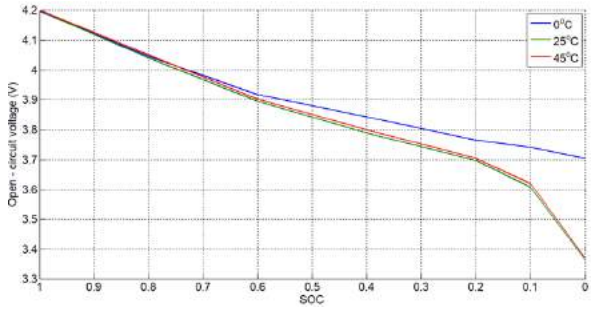


Fig-6: Open – circuit voltage of one battery module

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

Afer installing the rear wheel electric motor and controller, the original accelerator handle is replaced by electric accelerator knob. This knob is a variable resistor that determines the pulse width of the motor controller and thus the motor speed can be controlled.

Based on the same street and distance of 47 km, for gasoline mode and hybrid vehicle mode, it is recommended to use a battery pack that can be deeply charged.The results as shown in table 3 that can be saved 12.800 per distance of 47 km.

Table 3: Comparison between gasoline and hybrid mode with the distamce of 47 km

Configuration	*Cost (VND)*
Gasoline mode	20.000
Hybrid mode	7.200
Saving (per 47 km)	12.800

The figure 7 is also illustrated that for hybrid mode the hybrid motorcycle can be obtained distance father than that of gasoline mode with the same comsumption cost.

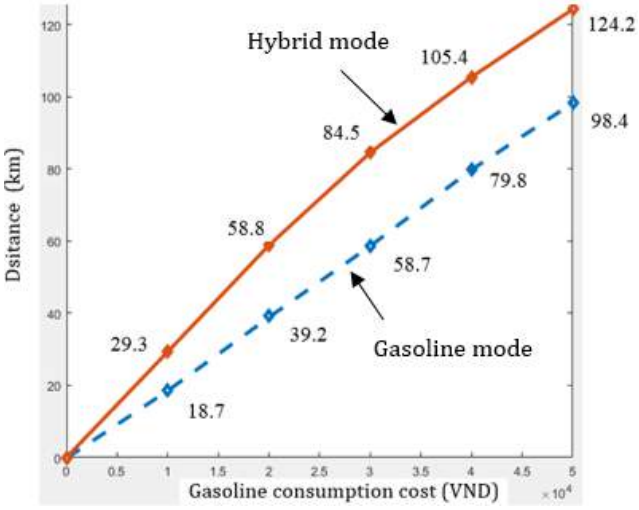


Fig-7: Comparison gasoline comsumption cost vs distance between gasoline and hybrid mode

4. CONCLUSIONS

This study discussed a novel powertrain for hybrid electric motorcycle with rear wheel electric motor. The experimental investigations are conducted to analyze and evaluate for the developed Hybrid system, to propose solutions to improve the efficiency of the hybrid transmission system on the motorcycle. The results show that plug – in hybrid structure without generator is the most feasible and effective choice to renovate a traditional motorcycle in traffic condition of Vietnamese cities.The study also illustrated that hybrid motorcycle can be improved fuel saving up to 0.5 USD per a distance of 47 kilometers comparison to theoriginal one.

ACKNOWLEDGEMENT

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