Design and Testing a Single-Passenger Eco-Vehicle

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Abstract. Protection of the living environment for sustainable development is a concern of mankind. In particular, reducing CO_2 emissions is the top criteria. A number of technologies that include a method of improving fossil fuel consumption effectiveness have been introduced into new automobiles in order to limit the negative effects caused by CO_2. In this paper, new technological solutions will be proposed. They are combined in a novel method in order to improve vehicle engine performance, to improve ignition and air return systems and to reduce friction between vehicle and environment when it is moving. The propsed method is applied into a new implemented vehicle for Eco Mileage Challenge (EMC) 2019 which is organized annually by Honda Vietnam Compapy. All tests and tournament results of 240 km per liter of RON98 gasoline in average prove that the propsed method is feasible and effective in fuel savings.

Keywords: Fuel savings · CO_2 emissions · Sustainable development · Green life

1 Introduction

Fossil fuels are increasingly exhausted. The use of fossil fuels as the main source of energy for people to convert to other forms of energy for essential human life such as electricity, mechanical energy has been increasing CO_2 emissions. Since its invention in the 20th century to the present, cars and vehicles have helped people move faster and more conveniently. This makes people dependent on them and this growing demand is the main reason for the increase in toxic gases such as CO and CO_2. With the goal of slowing down emissions or reducing them in the near future, a lot of new technologies in automobile manufacturing have been developed. Technologies aimed at reducing fuel consumption and exhaust emissions take time to be adopted by all manufacturers, thus their impact and payback time to the consumer will be close to a decade [1]. The fuel that vehicles consume depends on many factors, such as the vehicle mass, the efficiency of the powertrain, and the duty cycles imposed on the vehicle or powertrain [2]. In order to address the factor of vehicle mass, many significant efforts that can be found in [3, 4] have been made to reduce the weight. For the second factor, hybridization and electrification make the powertrain system more efficient [5–7].

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Recent progress in automatic driving technologies that include GPS-based or non-GPS-based [8] affects the third factor, duty cycles. Applied technologies in hybrid electric vehicles make it be are more fuel efficient compared to conventional vehicles due to the optimization of the engine operation and recovery of kinetic energy during braking. Therefore, they are represent a good and feasible solution to reduce fuel consumption and related emissions [9]. Moreover, focus on driver behaviour improvement for fuel consumption benefits is also taken into account in [10].

In this paper, all above factors and issues of vehicles and cars will be addressed. They are analyzed then solutions on vehicle engine, technology and vehicle electricity system will be proposed. They are detailed as follows: Sect. 2 decribes several solutions on engine, technology and electricity system with the aim of proposing a design method for fuel consumption reduction; testing results by the proposed method and discussion are in the Sect. 3 and conclusion will be given in Sect. 4.

2 Solutions and Design Method

2.1 Solution on Engine

Basically, the engine core is the cylinder with the piston inside moving up and down the cylinder. Single cylinder engines are typical of most lawn mowers, motobike. Cars have more than one cylinder such as four, six and eight cylinders in common. In a multi-cylinder engine, the cylinders usually are arranged in one of three ways: inline, V or flat (also known as horizontally opposed or boxer).

The engine going to be enhanced in this project is the single cylinder engine from Honda Vietnam Company. It consists of several parts such as Spark plug, Valves, Piston, Piston Rings, Connecting rod, Crankshaft and Sump.

The spark plug supplies the spark that ignites the air/fuel mixture so that combustion can occur. The intake and exhaust valves open at the proper time to let in air and fuel and to let out exhaust. Note that both valves are closed during compression and combustion so that the combustion chamber is sealed. A piston is a cylindrical piece of metal that moves up and down inside the cylinder. Piston rings provide a sliding seal between the outer edge of the piston and the inner edge of the cylinder. The rings serve two purposes: they prevent the fuel/air mixture and exhaust in the combustion chamber from leaking into the sump during compression and combustion and keep oil in the sump from leaking into the combustion area, where it would be burned and lost. The connecting rod connects the piston to the crankshaft. It can rotate at both ends so that its angle can change as the piston moves and the crankshaft rotates. The crankshaft turns the piston's up-and-down motion into circular motion just like a crank on a jack-in-the-box does.

The origin engine has been enhanced aims to reduce fuel consumption. It is shrunk and its weight dropped by half by cutting off unnecessary parts and components. The ignition steering wheel is also replaced in order to increase early ignition angle. The camshaft level is ground in order to reduce the force of the spring. The crankshaft is replaced by other higher level one on order to reduce the size of the combustion

chamber. The pot is replaced to increase engine torque. The concave piston is replaced by a convex one in order to reduce combustion chamber size.

The carburetor has been improved as well by several method which include utilizing a 35 cc electronic carburetor, using moderation to optimize the fuel line, reducing the size of the float chamber, using activated carbon for the return air option, increasing the fuel-wind ratio from 18:1 to 26:1.

For ignition, the direct method is employed and the Iridium multi-point spark plug is utilized in order to improve ignition system to create a strong spark.

For return air, the method of refluxing exhaust air by pump is used. The return hot air is taken from the hottest point in the engine.

All improved solutions have been proposed aiming to reduce fuel consumption when the vehicle moves on street.

2.2 Solution on Technology

Firstly, several new technology are applied. A digital electronic temperature sensor is utilized in order to monitor the temperature of the return hot air stream. In the other hand, the engine rotation speed, the vehicle speed are monitored by digital electronic multimeter devices. In order to determine fuel consumption, a liquid sensor is ultilized and a program is coded by employing the following algorithm:

$$\begin{cases} ignore \quad if \quad new\_level \geq last\_level \\ save \quad new\_level \quad if \quad new\_level \geq last\_level \end{cases} \tag{1}$$

A software uses GPS system in order to monitor the position and to display speed, gravity, distance and position of the driver when vehicle moving during the test is developed as well.

Secondly, several methods are employed in order to improve the friction coefficient which include using low-coefficient viscosity; viscosity by forced method to reduce friction in the gearbox; changing crankshaft ball bearing, camshaft ball bearing and ball bearings at the wheels and using the smooth/non-spiny wheels as well.

2.3 Solution on Electricity System

The vehicle's electricity system is designed, calculated by re-selecting parts that are no longer in accordance with the original design of the manufacturer, in order to optimize the vehicle's performance. The more powerful and accurate integrated circuit (IC) is used in order to achieve the best optimal fuel efficiency.

2.4 Design Method

Our proposed method is a scientific combination of solutions that affect on the vehicle engine, apply new technology into monitoring and controlling the vehicle electricity system in order to optimize its performance and to reduce fuel consumption.

Design of Chassis. The chassis is built enough for one driver to drive. In order to save fuel, the chassis mass is reduced and its surface is covered by a kind of low wind coefficient paint in order to reduce friction as much as possible. Metal types such as Iron, Stainless Steel and Aluminum are utilized to make the chasis in dimesion of 2400 mm in length by 500 mm in wideth by 800 mm in height and in weight of 32 kilograms. The chasis level from ground is 100 mm. Figure 1 shows the chassis details.

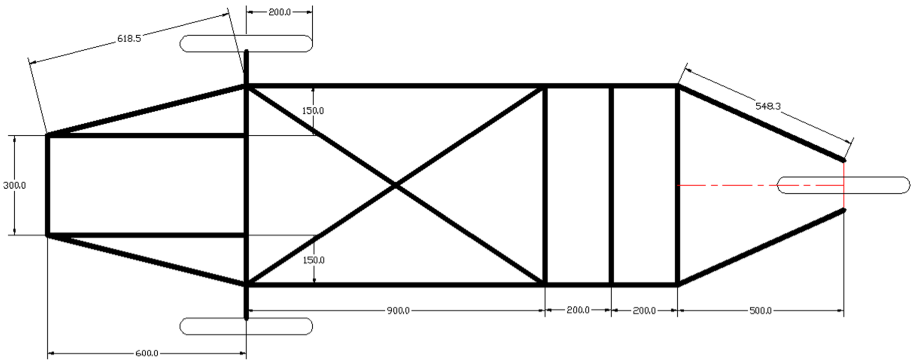

Fig. 1. Chassis drawing.

Design of Steering Mechanism and Clutch Separation Mechanism. It is made to fit the chassis. Specially, the wheel rotation angle is optimized in order to ensure the convenience in control.

Design and Implement of Vehicle Body. The vehicle body is designed based on the principles of aerodynamics to minimize friction that can cause and hinder the speed of the vehicle. Therefore, composite material is selected due to the lightweight but its firm and aesthetically.

In details, the composite material as following advantages:

- *Small specific weight.*
- *Good rigidity.*
- *Easy to work on any surface.*
- *Simple fabrication.*
- *High durability.*
- *Especially low processing costs.*

The vehicle body is made by utilizing following materials:

- *The no 2117 unsaturated Polyester resin type which is made in Singapore.*
- *The Mat 300 g/m2 glass fiber which is made by China.*
- *Curing catalyst of methyl ethyl keton peroxide (MEKP).*
- *Mold release agent, NaOH (10%), HCl (10%), seawater and distilled water.*

The vehicle body is made by following steps:

- *The mold is created. After processing the mold, its surface is cleaned and coated with a mold release agent.*
- *Clay, fiberglass and composite are applied on the mold later. Fiberglass is cut into shape and dried in minutes. The weight ratio of resin and fiberglass is 60 and 40, respectively.*
- *Conduct a retreading one by one layer of fiberglass.*
- *Roll the resin thoroughly into each layer so that the resin wet the yarn evenly and avoid the formation of air bubbles.*
- *After rolling is completed, allow to cure for 8 h at room temperature. However, drying should be better.*

Figure 2 shows the implmented vehicle body after casting.

Fig. 2. Vehicle body.

Design of Whole Vehicle. Other parameters and specifications of designed vehicle are listed in Table 1.

Table 1. Vehicle specifications.

Parameters	Specifications
Transmission ratio	6
Distance between 2 motor Shafts	460 mm
Driving posture	Sit down to drive
Steering angle Turning radius	8500 mm
Steering mechanism	Trapezoidal scales, rotating shafts, grippers
Winning structure	Disc brakes
Clutch separation mechanism	Directly from the engine

3 Testing Results and Discussion

3.1 Test at University

The implemented vehicle was tested on a distance of 9.5 km which is equal to the distance that it will have to perform at Honda EMC 2019. The driver is tasked to drive the implemented vehicle smoothly over several laps of school yard in order to complete

a round test of 9.5 km distance. The elapsed time for each round test is around 30 min. The fuel comsuption in milliliter for each round test was recorded carefully by high precision electronic fuel meter and shown as in Table 2.

Table 2. Testing records.

Round no	Fuel consumption [milliliters]
#1	53
#2	54
#3	52
#4	51
#5	49
#6	52
#7	46
#8	47
#9	48
#10	50

According to Table 2, the mean and standard deviation is 50.2 ± 2.66 [ml] per round test which means that the implemented vehicle could travel an average distance of 189.24 km with only 1 L of RON95 gasoline.

3.2 Performance at the EMC 2019

The Eco-fuel-saving Honda contest was first organized by Honda Vietnam Company in 2010. After 9 years of successful organization in Vietnam, the contest has attracted an increasing number of participating teams with achievements that are enhanced year by year. With the main challenge of "How many kilometers can you travel with 1 L of gasoline?", The Honda Eco Mileage Challenge (Honda EMC) contest is a playground where participants have the opportunity to apply their novel innovative ideas and unique technology into Honda's 4-stroke engine to create competitive vehicles in terms of fuel efficiency, travel the farthest distance with only 1 L of gasoline.

At Honda EMC 2019, each team performed 8 laps on a total distance of 9.5 km with an average speed of at least 25 km/h and an average time of 22 min 24 s. Fuel consumption efficiency (km per liter) is calculated based on actual fuel consumption and the team with the highest performance is the winner.

As a result, a team with implemented vehicle performed an average of 220 km per liter of RON98 gasoline and ranked in top 50 over 158 participating teams.

4 Conclusion

A desgin method of a single-passenger eco-vehicle has been proposed with solutions for innovation of vehicle body, improvement of engine and enhance of driving aiming to save fuel consumption. Many tests at university proved that ability in fuel consumption is low at 189.24 km per liter of RON95 gasoline. The standard deviation of 5.29% prove the stability of desgined vehicle in traveling path. The more detailed and scientific designs will be researched and implemented to optimize the ability of eco-vehicle fuel consumption in the future.

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