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APPLICATION OF CNG FUEL ON MOTORCYCLE ENGINES

Dong Nguyen Phu, Radek Procházka, Aleš Dittrich, Josef Laurin
Technical University of Liberec, Czech Republic

Nguyen Thanh Tuan
Nha Trang University, Viet Nam

ABSTRACT

With the strong development of motorcycles in Vietnam, it has directly affected the living environment and human health. The article analyzed and applied CNG gas fuel on Honda wave motorcycle engines with a carburetor fuel supply system. This contributes to reducing harmful emissions and reducing oil depletion pressure. The research team calculated and analyzed to come up with a solution to use two CNG fuel injectors in accordance with the design of the engine. Research results can confirm that the engine when using CNG runs stably and reliably. Engines operating CNG have reduced power and torque by 8% and 6%, respectively, compared to gasoline. However, converting gasoline engines to CNG fuel is easy, saving design and manufacturing costs, and can be applied and installed on vehicles already on the market. The installation requires no intervention in the engine combustion chamber and is simple.

Keywords: CNG; Fuel Injection System; Honda Wave Motorcycle.

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1. INTRODUCTION

CNG is compressed natural gas, the main component is methane (CH_4) taken from natural gas fields. Due to the absence of benzene and hydrocarbons, this fuel does not release many toxic gases such as NO_2 and CO when burned and almost does not generate dust [1-8, 12, 15]. In the world, CNG is used a lot to replace gasoline due to its advantages. CNG is easy to disperse, does not accumulate like gasoline vapor, and is safer than other fuels in the event of a spill because natural gas is lighter than air and dissipates quickly when released. If CNG is leaked into the atmosphere, the fire risk is less than half of gasoline, so the risk of fire and explosion is limited.

Fuel costs will be lower because the selling price of CNG is lower than other fuels in use. On the other hand, it reduces emissions into the environment of dust, fly ash, and harmful gases because CNG contains 85% of methane (CH_4). When burning, only CO_2 and water vapor are emitted due to the high combustion efficiency. Thereby meeting the standards of environmental health and safety according to current regulations. CNG can be found above oil fields, or can be collected from landfills or wastewater treatment plants [9]. In studies conducted by scientists around the world in using CNG for internal combustion engines, the results show that the engine power using CNG decreases from 10% to 18.5% compared to using gasoline in Vietnam. same load and speed mode because the intake air volume is reduced by 11% to 14.5% [1,3,9,11,13] due to the displacement of gaseous fuel and another reason is that the ignition angle has not been changed early because when keeping the same early ignition angle and not adjusting it to suit CNG, the combustion speed of CNG is slower than that of gasoline, which makes the combustion process not optimal.

More specifically, with each type of fuel supply system when using a mixer. The results show that the engine’s power when using CNG in the intake manifold is about 20% lower than when using gasoline fuel, but fuel consumption is improved by 11%. When converting the engine from using the mixer to using the direct air injection system, the test results showed that the engine efficiency increased quite a lot, and the engine's power increased by up to 10% compared to the case of using the engine using gasoline fuel with the same air residue factor. Thus, it can be seen that the CNG direct injection method will overcome the drawback of reducing the intake air of the fuel supply method on the intake line, thus improving the capacity. In addition, the direct injection method can also create a layered mixture, expanding the fire limit, and thereby increasing the thermal efficiency of the engine. However, the direct injection method is relatively complicated and expensive when converting gasoline-powered engines to CNG, so it is rarely applied.

In Vietnam, there have been initial studies on the use of CNG gas for engines. However, the application is not much except for the use of CNG for the bus fleet in Ho Chi Minh City. The causes are many, but like other alternative fuels, switching to a new fuel instead of gasoline requires good support from the state and infrastructure and solving the problem economy significantly. Before the above policies can be obtained, scientists need to make good technical solutions as an important basis for practical application. For the use of CNG for motorcycles Pham Tat Thang, Nguyen Xuan Tuan [5], have calculated and determined the basic parameters of the CNG fuel supply system to replace gasoline for JA31E engine, proposing an alternative. Improve the fuel supply system of the engine. Calculation and evaluation of the technical and economic indicators of the engine when using CNG fuel by AVL - Boost software. The calculation results show that the power and torque of the engine are both reduced by about 7 ÷ 12% compared to when using gasoline fuel. The JA31E engine using CNG still meets enough power for the Urban Concept eco-car to participate in the Shell Eco-Marathon competition and some other studies that only focus on simulation methods. It can be seen that the research and application of CNG for motorbikes in Vietnam is not much, while Vietnam has a motorcycle market that is ranked 4th in the world. The proof is that currently, the number of registered motorbikes by the end of 2020 in Vietnam is about 58 million units, and even if the impact of Covid 19 in 2020, the number of newly registered motorbikes will decrease but still reach 2,84 million vehicles. Thus, it can be said that studying a gas like CNG for motorbikes is appropriate and feasible in Vietnam.

Inheriting the research results published by scientists, the use of CNG fuel injection system on the intake manifold is suitable in the current situation with many advantages. Most importantly, there is no need to interfere with the engine because of the fact that with the Honda wave engine there is no longer a position to drill and install the injector directly into the combustion chamber. In which the fuel injection system is used from the electronic fuel injection system that is calculated, adjusted and installed to suit when using CNG fuel. The technical specifications of the motor are shown in Table 1.

Table 1. Engine specifications.

Wave alpha engine	Parameter
Engine type	4 - stroke
Number of cylinders	Single cylinder
Fuel system	Carburettor
Displacement	109.16 cc
Bore × stroke	50.0 x 55.6 mm
Cooling system	Air-cooled
Max power	5.2 kW
Max torque	8.54 Nm/5500 rpm
Effective fuel consumption	≤ 360 (g/kW.h)
Max speed	7500 rpm
Transmission	4 - speed

SELECTION OF INJECTORS CNG

With the goal of the research is to use CNG fuel system from wave motorcycle engine. Therefore, the injection pressure when using LPG is mainly adjusted by the fuel injection pressure for the fuel injection system (3 bar), the CNG fuel injection time by default of the control ECU of the injection system gasoline. However, there is a difference in that if this system is used correctly, the amount of CNG will not be enough, and the engine cannot start. The fuel injection system needs to be reformed by replacing another injector to ensure the corresponding injection flow when switching to CNG. The basis for selecting new nozzles is as follows:

Theoretically, the balance air/fuel ratio of gasoline A95 and CNG is 14.7 and 17.3, respectively. So when the wave engine uses gasoline or CNG, each cycle also requires an equivalent amount of air to be brought into the combustion chamber. To burn an equal amount of air, the gasoline/CNG ratio would be:

$$\frac{M_{Gas}}{M_{CNG}} = \frac{1/14,7}{1/17,3} = 1,18 \qquad (1)$$

From the formula, determine the amount of fuel through the nozzle cross-section (injector holes).

$$M = \mu.S.\sqrt{2\rho.\Delta p} \qquad (2)$$

Where: M is the mass of fuel, μ is the flow coefficient, ρ is the specific volume of the fuel, Δp is the pressure difference between the injection pressure and the intake manifold pressure.

The pressure difference between fuel injection and CNG is the same because the injection pressure adjustment when using gasoline and CNG is the same, considering the flow coefficient of gasoline and CNG is equal. So the mass ratio of gasoline and CNG will be:

$$\frac{M_{Gas}}{M_{CNG}} = \frac{\mu.S_{Gas}.\sqrt{2\rho_{Gas}.\Delta\rho}}{\mu.S_{CNG}.\sqrt{2\rho_{CNG}.\Delta\rho}} = \frac{S_{Gas}.\sqrt{700}}{S_{CNG}.\sqrt{180}} = 1{,}18.\frac{S_{Gas}}{S_{CNG}} \quad (3)$$

In which the density of gasoline is 700 kg/m^3, the density of CNG is 180 kg/m^3 (at a temperature of 25°C, compressed in a container) [14,17].

So S_{CNG} = 3,3 S gasoline.

This means that to use CNG fuel by the fuel injection system, the injector hole cross-section needs to be increased by 3.3 times.

Currently, for the fuel injection system for motorcycle engines, there are injection holes of equal cross-section, the difference between the total cross-section of the nozzles is equal to the number of injection holes. For the existing injector on the wave motorcycle fuel injection system with six holes, with the above calculation, it is necessary to have a 20-hole nozzle when used for CNG. However, this type is not available in the market. In this study, one more nozzle must be designed, and ten nozzle holes are selected for each nozzle. The installation of the nozzle on the intake manifold of the Honda wave motorcycle engine is shown in figure 1.


Figure 1. Actual image of 2 CNG nozzles installed on the intake manifold (left) and nozzle shape used (right)

3. SELECTION AND ADJUSTMENT OF PRE-IGNITION ANGLE

The position of the pre-ignition angle significantly affects the variation of the indicated pressure and the average temperature of the mixture in the combustion chamber. As the pre-ignition angle increases, the maximum pressure and maximum temperature increase accordingly, and the position of these maximum values is shifted to the dead point position. However, the work indicated of the motor does not increase in proportion to the maximum pressure or temperature. When the maximum point of the pressure shifts to the top dead center, the negative work due to the compression increases exceeding the increase of the positive part of the expansion process, so the indicated work of the motor is reduced. The electronic control ignition system provides an ideal ignition mode suitable for all vehicle operating conditions, the ECM determines the ignition timing based on signals from the sensors. In the memory of the ECM is stored the ignition timing for each operating condition of the engine. However, the main factor affecting the ignition timing depends largely on the engine's rotational speed. For Honda motorcycles, the optimum early ignition angle is in the range of 10-30 degrees before the top dead center corresponding to the smallest to the maximum engine speed [16,17,21]. When studying the optimal value of early ignition angle using CNG fuel. Studies have shown that the ignition advance angle needs to be increased from 5 to 15 degrees [2-6,16,18].

In Vietnam, typically, the work of Bui Can Ga et al., for motorcycles using Biogas whose main component is CH_4, similar to CNG, gives the optimal ignition angle increased from 6-10 degrees compared to that of CNG with gasoline with engine rotational speed from 3000 to 6000 rpm [16].

In the study of Nguyen Thanh Trung et al. [17] for 4-cylinder engines, the optimal ignition angle was also increased from 12 to 16 degrees compared with gasoline, corresponding to the smallest to largest rotational speed. When the CNG engine is operated at the optimum pre-ignition angle, the effective power increases by an average of 11.65% over the entire speed range.

Inheriting the above studies with the rotational speed of the Honda wave engine, the basic ignition timing can be adjusted up to 5 degrees compared to the gasoline engine [5,16,19], and the ignition angle is more effective tuning depending on the ignition already built into the ECM memory used by the manufacturer for gasoline engines. The adjustment of the ignition angle by adjusting the 9 jacks placed on the igniter is shown in figure 2.

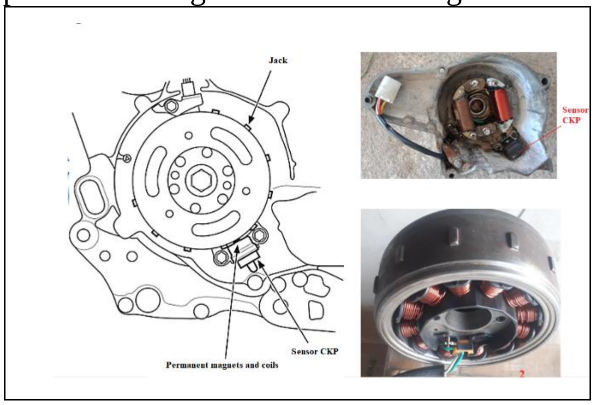

Figure 2. CKP sensor installation position on the machine (left image) and actual image (right two pictures).

4. INSTALLATION SCHEDULE

With the above-calculated data compared with the available fuel injection systems on the market, we find that the fuel injection system for the engine is appropriate. However, with the current conditions, when using fuel injection for CNG injection, it is necessary to add 1 extra injector and adjust the CNG fuel injection pressure accordingly according to the formulas calculated above. The equipment installation layout diagram is made as shown in Figure 3.

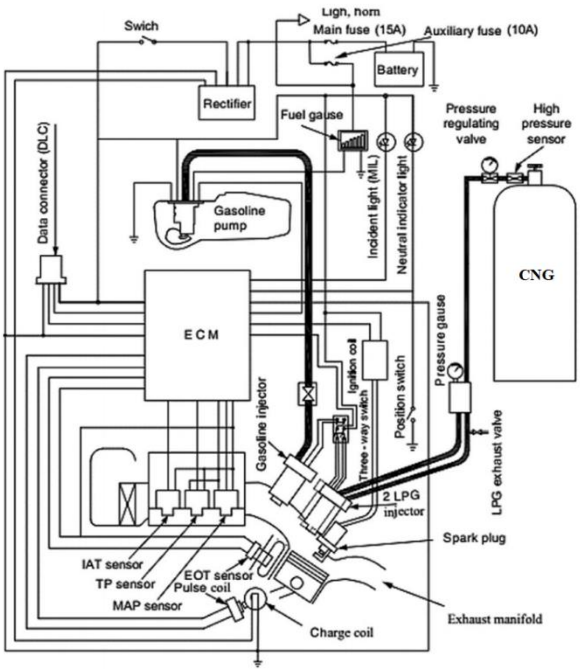

Figure 3. Equipment installation layout diagram

5. EXPERIMENTS AND ASSESSMENTS

After completing the installation and conducting a test run, it can be seen that the engine running CNG from the fuel injection system runs stably and does not feel the difference when running on gasoline. However, with comparable data, we experimented with measuring performance parameters on the test platform for evaluation. The experiment was conducted on the test platform (Figure 4) to compare the power and torque of the engine when switching to using CNG compared to using gasoline. The experiment was conducted at throttle opening modes 0%, 25%, 50%, 75%, and 100%.

Figure 4. The motorcycle is put in the test station at the laboratory.

Figures 5 and 6 are the experimental results shown on the graph showing the dependence of power and torque on throttle opening. The power curve when the engine uses CNG and gasoline is an increasing curve in the direction of increasing throttle opening. These two power lines have a certain difference. Engine power reaches the maximum value when the throttle opening is 75%, corresponding to 4 kW when the engine runs on gasoline and 3.5 kW when the engine runs on CNG, the power reduction reaches 12.5% when converting to CNG fuel.

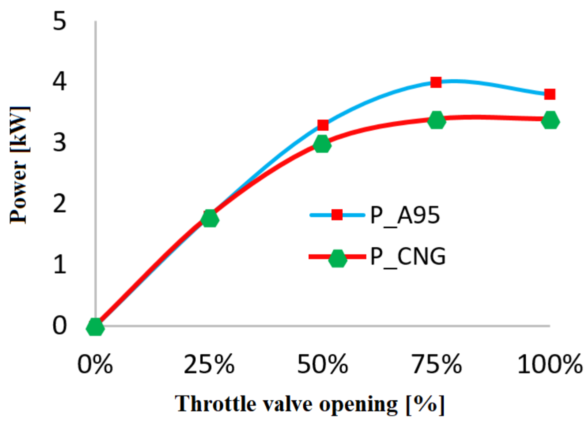

Figure 5. Comparison of engine power when using gasoline and CNG in throttle opening modes.

As for the engine's torque, the two curves showing the torque in the two cases of gasoline and CNG also have a significant difference.

Torque reaches the maximum value at throttle opening between 50% - 75%, when using gasoline, the maximum torque is about 6.3 Nm, and when using CNG is 5.9 Nm, reducing 6.3 Nm %. After this throttle opening, the engine torque in both cases of fuel use tends to decrease gradually.

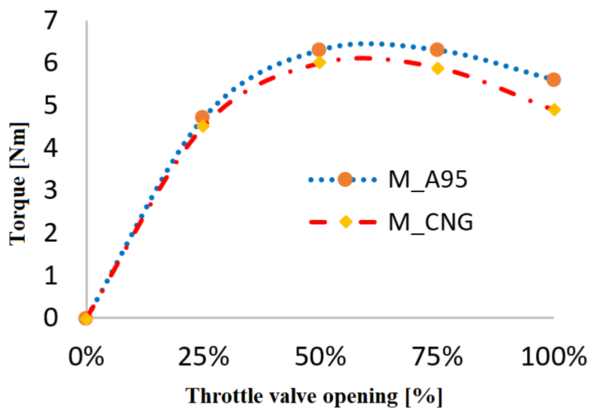

Figure 6. Comparison of engine torque when using gasoline and CNG in throttle opening modes

It can be seen that the power and torque of the gas engine using the CNG fuel system in this study are reduced compared to that of the gasoline engine. The cause of this reduction may be due to the fact that the density of CNG is small compared to gasoline, with the same engine, the cylinder volume can only accommodate a certain amount of gas (gasoline + air) and (CNG + air) are equal in volume. Therefore, calculating the volume so that the volume of CNG is replaced by the volume of gasoline when converting will lead to this amount of CNG being injected into the combustion chamber, which will occupy a part of the volume of air (lack of air), this is the main cause leading to the reduction of power and torque when using CNG fuel. This analysis is also suitable when in the low throttle opening mode the difference is not much and when the throttle opening mode is larger, the difference in power and torque is larger. Usually, in low throttle mode or low engine speed, the fuel needs to be denser; at high speed, the fuel will be thinner (smaller air residue factor). This result is also consistent with the previous publications of scientists when studying CNG instead of gasoline in different types of engines [6,8,12,21]. However, according to this analysis, to improve capacity, a turbocharger can be used to push more air into the combustion chamber.

6. CONCLUSION

The study calculated and installed a complete CNG fuel supply system based on the fuel injection system of a similar available engine. Experiments can confirm that the use of CNG fuel supply system gives relatively reliable results. The average power and torque in the experimental modes when using CNG are reduced by about 8% and 6% respectively compared to when the engine uses gasoline. However, this is a simple solution, easy to install, and does not need to interfere with the engine structure. The implementation of CNG application on Wave alpha motorcycle engine is completely possible, simple technical solution does not cost much and has high applicability. However, in order to perfect the engine's power and torque, further research directions are also needed to focus on using turbochargers, choosing the optimal early ignition angle, etc. In addition, there should also be a reasonable solution for this arrange CNG tanks on motorbikes.

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