RESEARCH ON SETTING UP TYPES OF CONTAINING METHANE FUEL INJECTION SCHEMATIC FOR SPARK IGNITION ENGINE USING JUKEN SOFTWARE

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(Received: May 08, 2025; Revised: June 08, 2025; Accepted: June 21, 2025)

DOI: 10.31130/ud-jst.2025.23(9B).512E

Abstract - With the strong shift in the use of alternative energy sources for gasoline engines on waterways and road vehicles, the concentration of toxic emissions into the environment will gradually be reduced according to the roadmap towards net zero by 2050, according to Vietnam's commitment at COP26. With this goal in mind, the article presents the results of a research test of an engine using biogas. The research engine is a Honda JA52E gasoline engine with a pre-set ECU and Juken engine control software connected to a computer. Thanks to the support of Juken software and devices connected to the engine, the methane fuel injection diagram containing the engine intake manifold was calibrated and established. The stable engine operation with a suitable diagram opens up future in-depth research directions in using engines containing methane fuel of different compositions, impurity ratios, and possibly many other alternative fuels to gasoline.

Key words - Biogas; methane; carbon dioxide; engine; juken

1. Introduction

This is because traditional fuel sources such as gasoline and diesel are gradually depleted, and at the same time, the problem of air pollution is caused by engine emissions. These are the main reasons why many alternative fuels, including methane, are being used to meet the above requirements. This gas is produced from petroleum and is called compressed natural gas [1]; if produced from biomass, it is called syngas; produced from animal manure, it is also called biogas. Although the main component is methane, it always contains impurities depending on the type; it will have different components; methane can only account for 60% of the composition.

Methane is a fuel that can be used instead of gasoline and diesel. Burning methane produces fewer unwanted toxic gases. It is safer than other fuels in case of spills because methane is lighter than air and disperses quickly when released.

Following the general trend of the world, in Vietnam, there have been many studies on using dual fuel or partially mixing new fuels with gasoline or diesel. With methane gas, the projects focus on using CNG natural gas and Biogas for small gasoline engines, mainly focusing on the strong research group of Professor Bui Van Ga [2] at Da Nang University. The group's research results have shown the outstanding advantages of Biogas in improving the concentration of toxic substances released into the environment. The simulation study of supplying CNG fuel to the high compression ratio Kamaz 740 engine by author Le Van Tuy [3] showed that CNG can be injected in two stages without detonation, and the injection amount can be controlled and quantified by electronic control. However, the author's research only stopped at simulation calculations without experimental research to have more complete assessments of economic and technical indicators as well as toxic emissions of the engine. Another study using CNG was conducted by Nguyen Si Thang [4] on two Innova and Altis cars. The original engines were all equipped with electronic fuel injection systems. The research team installed a CNG supply kit using a mixer for the engine and conducted laboratory tests with two types of fuel: gasoline and CNG. The results showed that the capacity of the two cars was reduced by 11.6% and 19.4%, respectively, CO emissions were reduced by 60 ÷ 100%, and CO_2 was reduced by 21 ÷ 23.5%.

Available kits that can help users convert gasoline engines to CNG are easily sold in China and India. However, the price of available kits is quite high, and sometimes, it is not easy to match the user's specific engine to ensure the required economic and technical features. Therefore, the research and manufacture of the main components of the CNG supply system, such as the mixer or the injection controller, to ensure the supply of CNG suitable for the converted engine is always being studied. Methane gas, in general, and CNG, in particular, can be considered a clean fuel source because when used, the emission of toxic gases such as COx, NOx, and SOx is reduced [7-10]. Implementing the national target program on energy saving and efficiency while meeting environmental protection requirements, the Ministry of Transport has assigned the Maritime University to research the possibility of converting CNG liquefied petroleum gas fuel to replace traditional diesel fuel for small-sized marine diesel engines. The successful conversion to use liquefied petroleum gas fuel for diesel engines is of great economic significance due to reducing fuel costs for engines, saving fossil fuel resources that are gradually depleting, ensuring energy security, taking advantage of natural gas sources along with biofuels, biogas, biodiesel... besides contributing to reducing environmental pollution from emissions from marine diesel engines. The research and application of CNG fuel for small-sized marine engines was conducted on the K657 M2 6×12/14 hybrid diesel engine with a capacity of

50kW from the former Soviet Union. The research focuses on studying the physical and chemical properties of CNG fuel, characteristics of the combustion process of CNG in the diesel engine working cycle, fuel conversion system, technical parameters of the engine when using CNG, the toxicity of exhaust gas, and economic efficiency of applying this fuel [5]. Thematic studies have achieved many positive results.

The results of exhaust gas concentration analysis also show that compared to Vietnamese standards, the concentration of toxic substances (NOx, SOx, and soot) in the exhaust gas when the engine uses methane fuel, especially NOx gas, is much lower than the allowable limit even at the standard mode.

The advantages of methane gas, which is essentially a gas available or in the production process such as CNG, biogas, and syngas, in reducing environmental pollution have been confirmed by studies around the world and even in Vietnam. However, using these types of gas causes certain difficulties in engine operation. For example, starting when the engine uses biogas and syngas with impurities up to 40% will be difficult. Therefore, this study will focus on engine operation when using methane mixed with 40% CO_2; this is a gas that hinders the combustion process of fuel and is also one of the main impurities in biogas and syngas products. Adjusting the fuel injection ratio based on Juken software so that the engine operates stably at the above fuel ratio is the basis for the engine to be able to use many different types of fuel, such as CNG, syngas, and biogas.

2. Experimental equipment

2.1. Engine and fuel system

The study was conducted experimentally on the Honda JA52E engine equipped on the Wave RSX FI 2014 using electronic fuel injection. The fuel used is methane and carbon dioxide taken from 2 injectors. An additional nozzle is installed on the intake pipe to use these two types of gas for the engine. One nozzle is for injecting methane, and one is for injecting carbon dioxide into the intake pipe; these two gas streams are mixed with air before entering the combustion chamber. The engine's technical parameters are shown in Table 1. The experimental engine and the Juken software interface controlling the engine are shown in Figures 1 and 2.

Table 1. *Engine specifications [5]*

No	Parameters	Value	Unit
1	Cylinder volume	109	cm^3
2	Cylinder Diameter	50	mm
3	Piston Stroke	55,6	mm
4	Compression Ratio	9,3:1	-
5	Power	65	kW/7500 rpm
6	Torque	8,77	N.m/6000 rpm
7	Maximum RPM	10000	rpm
8	Minimum RPM	1000	rpm

Figure 1. *Experimental equipment layout*

2.2. Juken 5 software

The engine has devices to calibrate parameters such as air-fuel ratio, engine speed, etc. In addition to basic details such as sensors and control ECU, the ECU is also connected to Juken software to calibrate appropriate fuel injection time. The software interface is described in Figure 2.

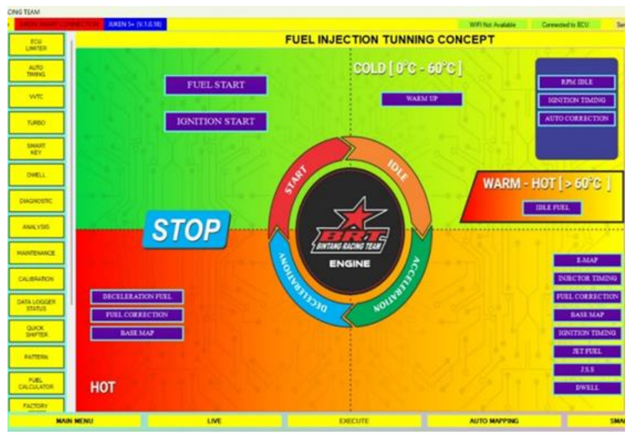

Figure 2. *Interface of Juken software in engine control.*

3. Fuel injection diagram setup

The basic fuel quantity depends on the amount of air intake and the engine speed. According to Khoi's research [5], the formula can represent the amount of fuel for each cycle.

$$G_{nl} = 12.291 \times 10^{-11} \times p_a \times 0.7 \quad (3.1)$$

Where G_{nl} is the mass of fuel per cycle, P_a is the atmospheric pressure. The formula determines the theoretical amount of fuel for each cycle, which serves as the basis for establishing the basic fuel injection diagram from Juken software.

We can calculate the amount of fuel needed for each cycle by formula 3.1. The air pressure in the intake pipe is described in Figure 3, and the pressure unit is Pascal.

The density of Syngas at the ratio of 60% CH_4 and 40% CO_2 at 24^0C is ρ_f = 1.186 kg/m^3. The absolute pressure of fuel on the intake pipe leading to the injector nozzle is p_{nl} = 4kg/cm^2 = 392266Pa. This value is set according to the air tank pressure and the opening of the air valve to the engine intake manifold.

From the basic amount of fuel injected for 1 cycle, we can calculate the injector opening time

$$t_{inj} = \frac{G_{nl}}{\rho_f \times A_{eff}} \times \sqrt{\frac{\rho_f}{2\times(p_{nl} - p_a)}} \quad (3.2)$$

Based on the theoretical injection time calculated according to formula 3.2 as the basis for adjusting the appropriate injection time for each fuel injection mode of the engine on Juken software.

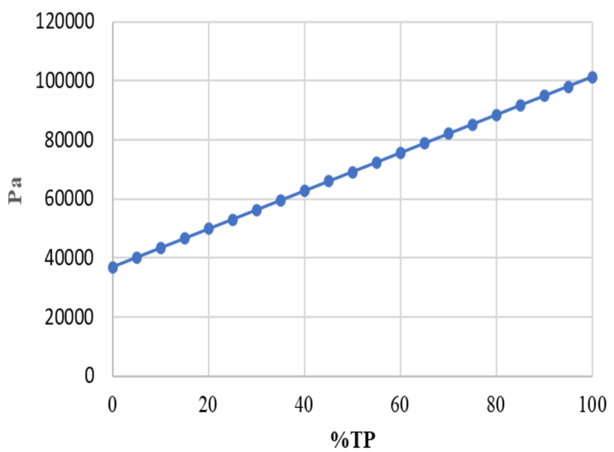

Figure 3. *Graph showing the dependence of intake manifold pressure on throttle opening [5]*

4. Set up and calibrate the fuel injection timing diagram with Juken software

To establish an injection diagram for fuels containing methane gas. Common fuels include CNG, syngas, and biogas. These fuels have very different methane gas components. However, this is a typical study in the application of Juken software to establish an injection diagram, so we choose a fuel with 60% methane gas and 40% impurities; the amount of impurities in this study is chosen as carbon dioxide gas, a typical gas in the mixture of biogas and syngas to be used as a sample for research.

The theoretical calculation results show that at the closed throttle position (0% TP), the injection time is 10.01 ms, and at fully open throttle mode (100% TP), it is 30.28 ms.

From the theoretical fuel injection diagram, we operate the engine with a ratio of CH_4 60% and CO_2 40%, corresponding to a pressure of CH_4 = 5.5 kg/cm^2 and CO_2 = 1.7 kg/cm^2.

After running the engine, we check the test results using the Data logger feature. However, in this theoretical injection map, the engine is not stable. When the engine operates at a throttle opening higher than 30%, the engine becomes unstable and vibrates strongly. With the advantage of Juken software, the study proceeds to adjust the air and fuel ratio to be more suitable.

We proceed to calibrate the injection duration value in Fuel Correction in Live mode. The basis for calibration is the AFR ratio during the test run.

The "Fuel Correction" feature directly shows the engine's operating status through signals from the engine's sensors and marks the areas where the engine has been operating. The program calculates the direct results when the engine is running based on the available oxygen sensor on the engine. There may still be many errors, but it also provides more basis for us to adjust the injection time more reasonably.

With this injection diagram, the engine works stably when operating at different throttle openings; there is no more vibration or automatic stop. Thus, this injection diagram suits methane fuel mixed with 40% carbon dioxide impurities. The input sensors receive good signals, the ECU calculates and controls fuel injection, and the ignition operates accurately and reliably. Therefore, it is possible to change the fuel injection map flexibly to suit each fuel situation. Suppose the ratio of methane and carbon dioxide fuel components is adjusted. In that case, the larger the CH4 component in the mixture, the shorter the injector lift time and the smaller the AFR ratio. Because at this time, the fuel contains more combustible components such as CH4, even if the injector lift time is shorter, there is still enough fuel to fuel the engine, and the air-fuel ratio is reduced because the amount of fuel burned increases. In comparison, the amount of air remains unchanged compared to other tests.

The basic injection duration from the software in Figure 4 is a planar graph that shows the linear change in injection timing according to engine speed and throttle opening. However, the results of adjusting the injection duration to match the actual operating modes of the engine are shown in Figure 5. With the adjusted injection duration, the engine works more stably and we can easily adjust the fuel injection diagram when the fuel composition changes or when switching to using other fuels instead of gasoline. This is the basis for more in-depth research in using Juken software to adjust the fuel injection map, reducing effort, cost and research time.

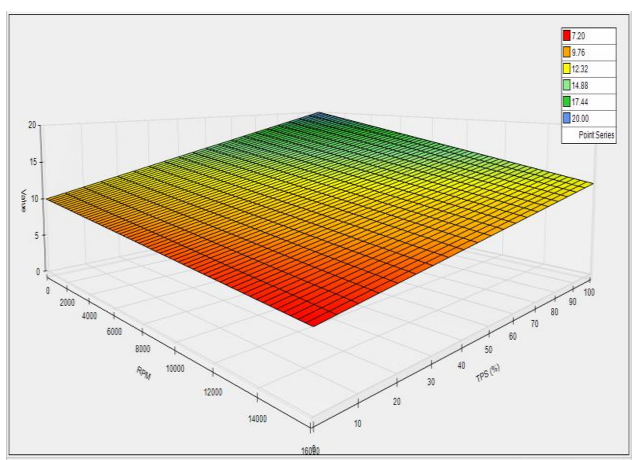

Figure 4. *Theoretical injection time diagram*

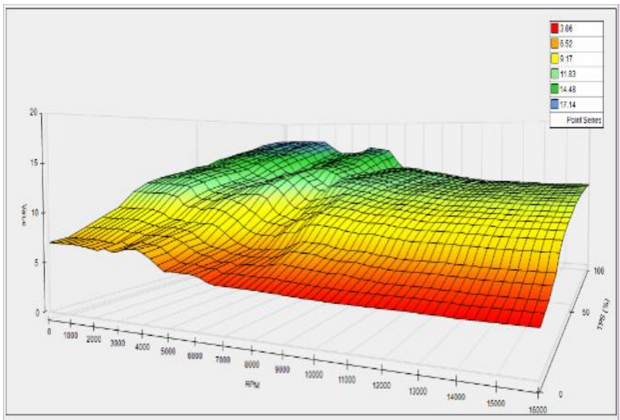

Figure 5. *Calibrated injection timing diagram*

5. Conclusions

In this study, the engine can use methane gas as a substitute for gasoline in conditions where methane contains many impurities. Under experimental conditions at idle, the engine operates in many modes when adjusting the throttle positions.

Using Juken software, it is easy to calibrate the injection diagram to suit each operating mode of the engine. This opens up opportunities for setting up fuel injection diagrams for the engine when using methane fuel with many different components and impurity ratios, as well as for many other alternative fuels for the engine instead of gasoline.

However, for the engine to operate stably at different load modes or minimize pollutants caused by this gas, other in-depth studies are needed in the future when conducting experiments on the power test stand and devices measuring the concentration of exhaust gas from the engine.

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