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A STUDY ON IMPACTS OF CNG SUPPLYING METHOD ON THE INTAKE MANIFOLD TO OPERATION OF TRANSFERRING GASOLINE ENGINE

VanTuan Nguyen
University Of Transport Technology, Hanoi, Vietnam

MinhHieu Pham
Hanoi University of Industry, Hanoi, Viet nam

ABSTRACT

When supplying CNG to the engine in the intake manifold, two methods can be used: the mixer and the injection system. Each method has its own strengths and weaknesses. Hence, to evaluate the effectiveness of each method, there highly neccessary should be a veryfication via testing. In this study, the authors dug deeper in calculating the design of the mixer and the CNG injection system then proceeded to experimentally evaluate the results. The results showed the effects of CNG-granting methods on power, fuel consumption and emission rate of CO, HC, NOx components ~~of~~ from the engine. In particular, when using CNG, the power engine reduced to 20.8% for the use of blenders, a decrease of 15.9% for the use of injection systems; Fuel consumption was reduced by 2.4% and 5.4%, respectively, when using these two gas supply systems. CO and HC emissions decreased by 85%, while NOx decreased by 58% for both methods of supply.

Keywords: CNG gas, CNC gas engine, Mixer CNG, CNG injection system.

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1. INTRODUCTION

In order to ensure long-term energy security, reduce environmental pollution and sustainable development, many countries in the past few decades have focused on the use of alternative fuels, clean fuel industry in his country [1]. Therefore, experts in the domain of automobile have come up with the direction of using alternative fuels. Current alternative fuels are natural gas, biodiesel, hydrogen, and so on. One of the research directions that are being developed is natural gas. Natural gas is also obtained from fossil fuels, which is similar to gasoline and diesel fuels. However, natural gas can be considered as renewable energy due to its high methane content[2].

The merits of CNG as an automotive fuel over conventional fuels are many and presented comprehensively by Nylund et al [3]. Due to some of its favorable physio-chemical properties, CNG appears to be an excellent fuel for the spark ignition (SI) engine. Moreover, SI engines can be converted to CNG operation quite easily for with the addition of a second fueling system.

Recently, research on the use of the NGV and gasoline base engine performance [4-6], where they found the volumetric efficiency of the NGV engine is reduced by about 15% and overall performance lowered by circa 9% at maximum torque and maximum power conditions. BSFC of NGV engine is reduced from 15 to 22% at speeds 1500–3500 rpm, for the same air fuel ratio (AFR). Compared to the base petrol engine, CO and HC reduction of between 40–50% and 35–50%, respectively, were achieved.

Research the CNG injection directly into the engine cylinder [7]. The authors experimented on a four-stroke petrol engine using two types of gasoline and CNG fuels. The results show that when the engine uses a direct injection system, the engine efficiency increases dramatically, the engine power increases by up to 10% compared to gasoline using the same coefficient of air residue.

Thus, in terms of principle, it can be seen that direct injection CNG method will overcome the disadvantages of lowering the intake method of fuel delivery on the loading path should improve the capacity. However, the direct injection method is relatively complex, costly to convert, engine conversion is using gasoline fuel to CNG so also less applied. The relatively simple CNG delivery method is applicable to gasoline engines in circulation because most of these engines are equipped with electronic fuel injection systems, which is very convenient for Design and manufacture of CNG feeder. However, the efficiency of CNG engines depends on the way the engine is mixed. In this paper, the authors study the methods of supplying CNG on the way to economic and environmental criteria so that they can choose the most suitable method of supplying gas.

2. CNG SYSTEM DESIGN

2.1. Engine specifications converted to CNG

To assess the effects of CNG supplying methods to performance the load modes and speed stability of the engine. Because of study uses the 5A-FE engine. The 5A-FE engine is a four-cylinder gasoline engine that uses a multi-point gasoline fuel injection system. The basic parameters of the motor are shown in Table 1.

Table 1 Basic specifications of 5A-FE Engine.

Parameter	Sign	Value
Displacement (cc)	V	1498
Stroke (mm)	S	84,7
Diameter (mm)	D	75
Number of cylinders (-)	I	4
Maximum power (kW@rpm)	Ne	78@6000
Maximum torque (Nm@rpm)	Me_{max}	131@4800
Minimum fuel consumption (g/kW.h)	ge	244
Compression ratio (-)	ε	9.8:1

2.2. Chemical composition of CNG fuels

Natural gas is a colorless, odorless gas that is slightly lighter than air and is classified according to the composition of each specific gas sample. Natural gas contains the main constituent of methane and some other gaseous components with smaller ratios; Dried gas containing high methane content and wet air contains significantly higher amounts of some higher molecular weight hydrocarbons belonging to alkanes such as ethane, propane and butane [8-9]. Natural gas that is extracted and processed in different regions under different conditions will have different levels of constituents. Table 2 shows the composition of a sample of natural gas used to serve research in the study.

Table 2 Basic components of natural gas used in experiments

Component	Sign	Content (%)
Methane	CH_4	93,3
Ethane	C_2H_6	2,16
Propane	C_3H_8	0,19
Ethylene	C_2H_4	0,14
Nitrogen	N_2	2,21
Carbondioxide	CO_2	2,00

2.3. CNG supply system using mixer

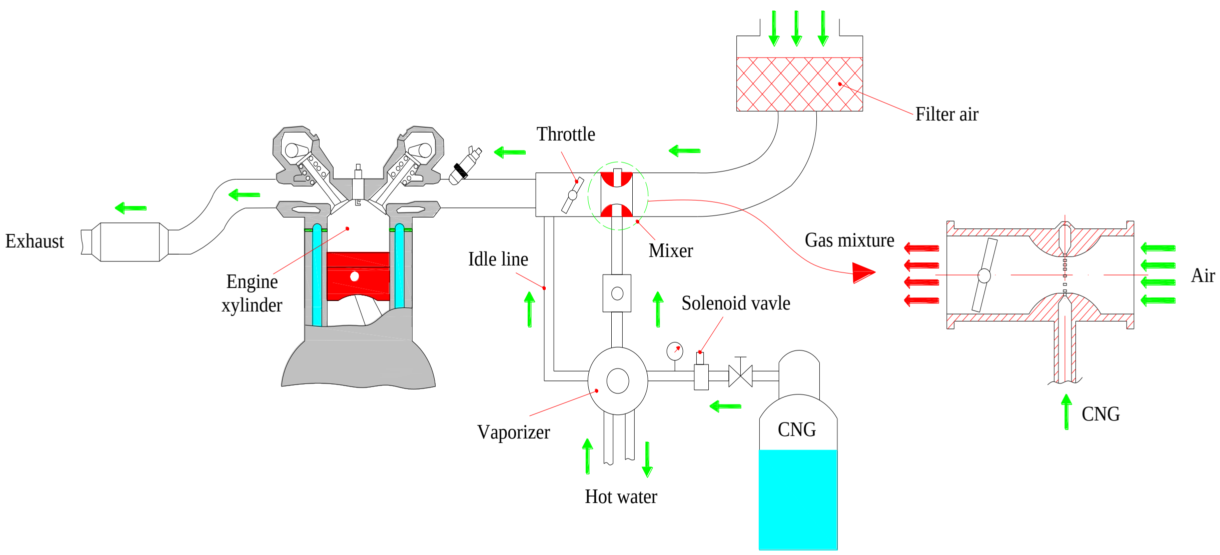

Figure 1 Diagram of CNG supply system with mixer

The mixer is an important part of this CNG supply system, which is responsible for quantifying CNG and mixing CNG with air at a suitable rate to form an air mixture into the engine.

From the basic dimensions defined above and the size and position characteristics of the general intake manifold of the engine, the other dimensions of the mixer are defined and the manufacturing drawings are shown in Figure 2.

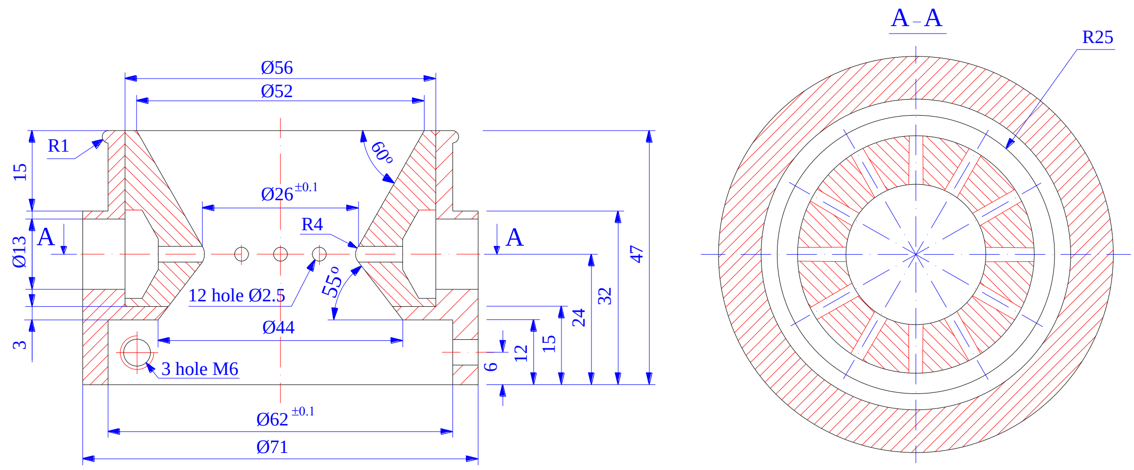

Figure 2 Mixer texture drawing

2.4. CNG injection system into intake port

The CNG fuel injection for the engine in this study was carried out by multi-point injection into the intake in the working order of the engine cylinder. Control of fuel injection change is accomplished through a control of the change in the length of the injector opening while the pre- and post-injection pressure differential is adjusted to hold at 3 kG/cm^2. Injection control is performed by varying the signal pulse width to the injector by the electronic controller. This method makes it easy to accurately adjust the amount of fuel injected according to the different working modes of the engine. Sequential injection method ensures consistent mixing quality between cylinders.

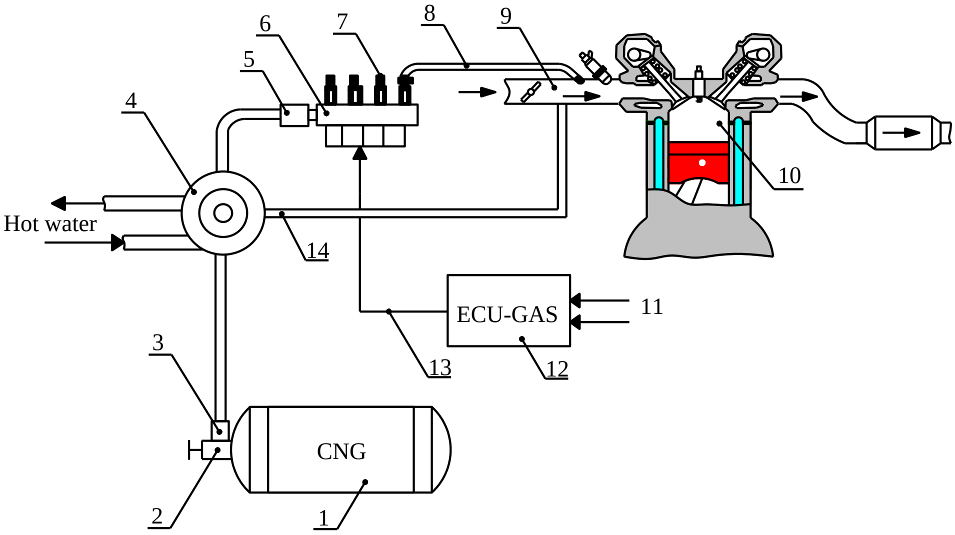

Figure 3 CNG injection system diagram

1. CNG tank
2. Mechanical valve
3. Solenoid vavle
4. Vaporizer
5. CNG filter
6. Rail
7. Injector
8. Nozzles
9. Intake manifold
10. Engine xylinder
11. ECU-Gas
12. ECU gas
13. Control signal line from the ECU
14. Vacumm line

3. BUILD THE EXPERIMENTAL DIAGRAM

The test strips are shown in Figure 4. The APA100 electric brakes operate in two modes: electric motors and generators. With electric motor mode, the APA100 electric brakes are capable of operating at a rated power of 200kW in the speed range of 2250rpm ÷ 4500rpm and rated torque of 849Nm in the speed range of 0 ÷ 2250rpm. When the APA 100 electric brake operates in generator mode, the rated power is 220kW in the speed range of 2250rpm ÷ 4500rpm and rated torque 934Nm in the speed range of 0 ÷ 2250rpm.

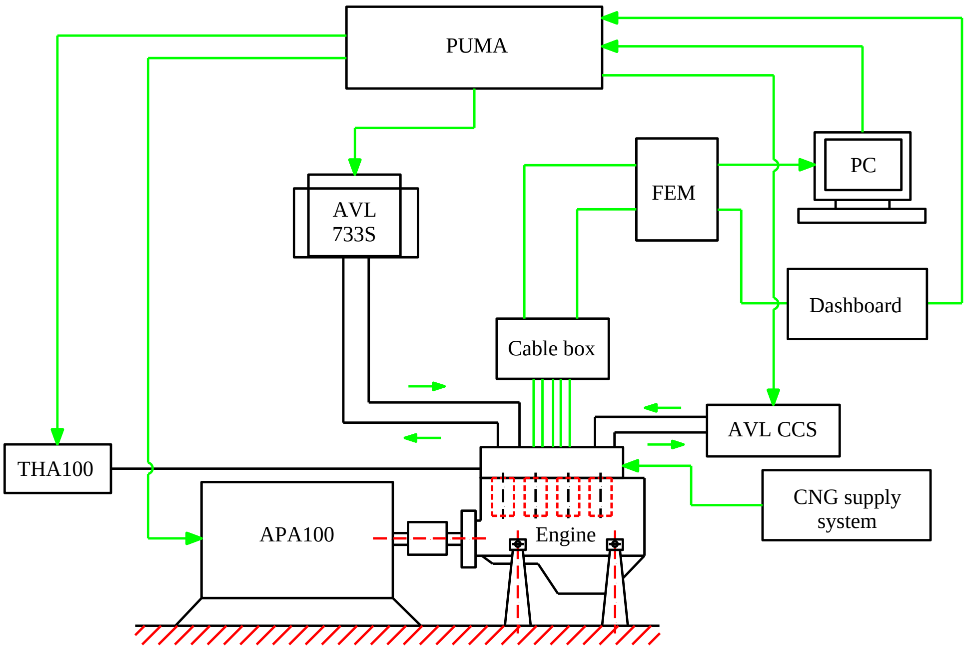

Figure 4 Diagram of arrangement the experimental equipment

4. EXPERIMENT AND RESULTS

4.1. Evaluate the power rating of the engine

The assessment of engine power rating using CNG fuel with mixer, CNG injection engine compared to that of the original gasoline engine using commercial gasoline RON 92 was done in the working mode on the external characteristic line. The test results for measuring engine power and evaluating the change of power for the fuels are shown in Figure 5.

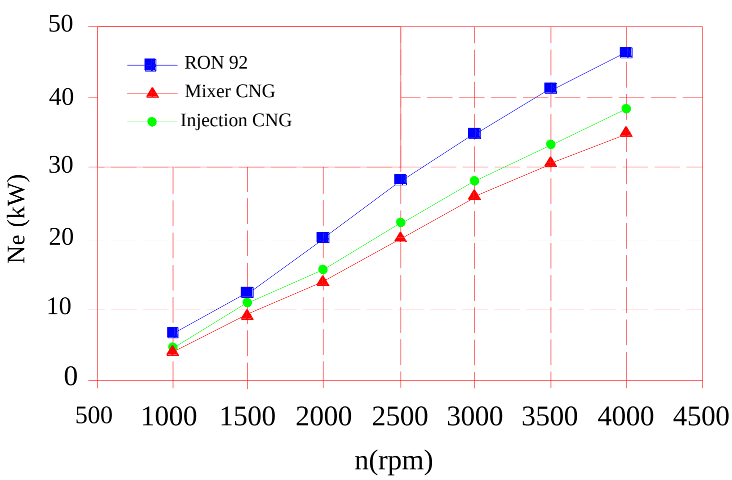

Figure 5 Engine power at off-road characterization using RON 92, CNG mixer, CNG injection

The results on the graphs show that the engine's power consumption when using CNG is much lower than the original engine power of RON 92 gasoline with a multi-point electronic fuel injection system. In the case of using CNG with mixer, the engine power was reduced considerably, 20.8% on average, over the whole speed of the test, whereas in the case of CNG injection systems, the power the engine only decreased by 15.9% on average compared to using RON 92 gasoline.

If comparing CNG power with CNG mixer and CNG injection engines, CNG injection engines are 5.9% more powerful than CNG engines using mixer.

4.2. Evaluate the fuel consumption of the engine

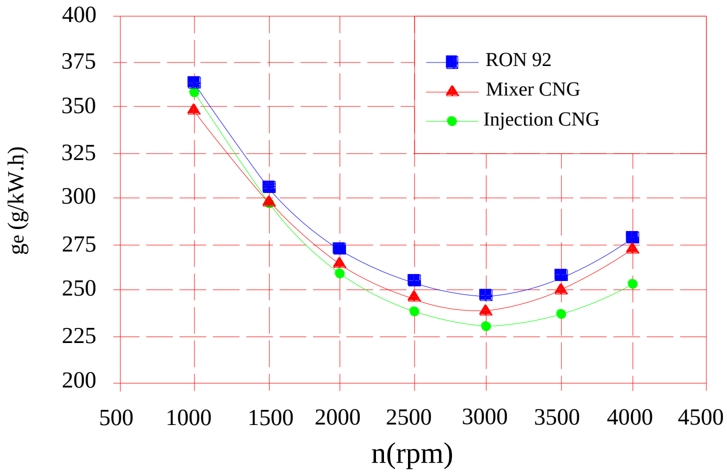

Figure 6 Fuel consumption of the engine in external characteristics when used RON 92, CNG mixer, CNG injection

The economic evaluation fuels of the engine when using CNG fuel with mixer, CNG injection versus conventional gasoline engines using RON 92 gasoline was done by comparing the fuel consumption of the engine CNG engines when using the above fuel supply systems with engines when using gasoline. Comparative evaluations are made in the modes of work on the external characteristic path and load characteristics. The test results are shown in Figure 6. The test results show that, over the whole range of speed and load when using CNG, the fuel consumption of the engine is significantly reduced compared to using gasoline.

At external characteristics (Figure 6), overall fuel consumption is quite high at low speeds (over 350g/kW.h at 1000rpm), decreasing rapidly as speed increases and reaches the smallest speed 2500rpm ÷ 3500rpm. This is an area of economic speed and also the speed of the engine. When using CNG with mixer, the average fuel consumption was reduced by 2.4% compared to gasoline. In this case, the engine output decreased by an average of 20.8% as mentioned above but the fuel consumption was not only increased but decreased by 2.4%. The reason is that the volume of CNG fuel supplied to the engine is much lower than the petrol fuel while the CNG fuel mass (50 MJ/kg) is higher than the petrol value (44 MJ/kg) 13.6%. Engine using CNG injection system has 3.1% lower fuel consumption compared to using CNG system with blender and 5.4% lower than the fuel consumption when used. RON 92. The reason is because the aerodynamic losses and the cogeneration mixture of the CNG injection engine is lower than the CNG engine using the mixer.

4.3. Evaluate engine emissions

Results of the test of the content of toxic emissions of the engine are carried out simultaneously with the measurement of power and fuel consumption of the engine. The results are shown in Figures 7 to 9.

CO Emission

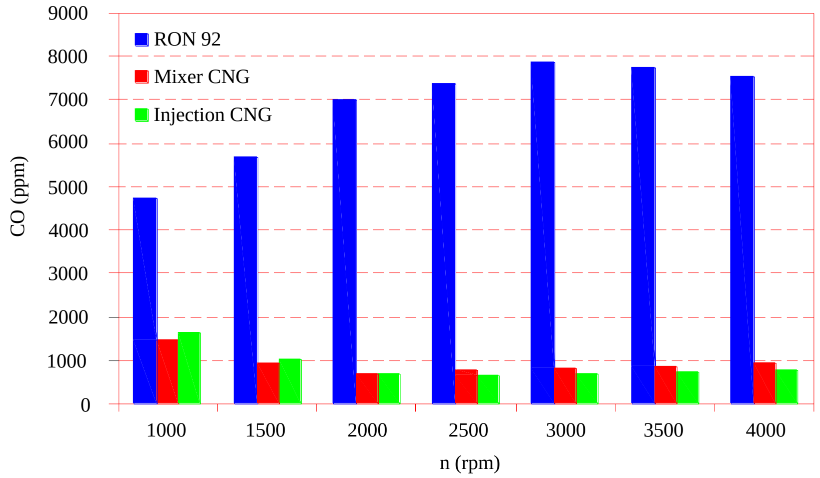

Figure 7 CO emissions at full load at different speeds when used gasoline RON 92, CNG mixer, CNG injection

The results of the measurement of CO emission at full load modes on the external characteristic path of the engine are shown in Figure 7. The results show that, across the speed range of the characteristic line, the CO emission of the engine CNG engines are significantly reduced compared to engine emissions when using RON 92 gasoline. The CO emission reductions range from 66% to 92%, the average reduction of about 79%. The CO emissions of CNG injection engines have improved compared to CNG engines using the mixer but not much improvement. The CO emissions of CNG injection engines at 1000 rpm to 2000 rpm increases form 3% to 10%, from 2000 rpm onwards, the CO emissions is decreased from 13% to 20% compared to CNG engines using the mixer

HC emission

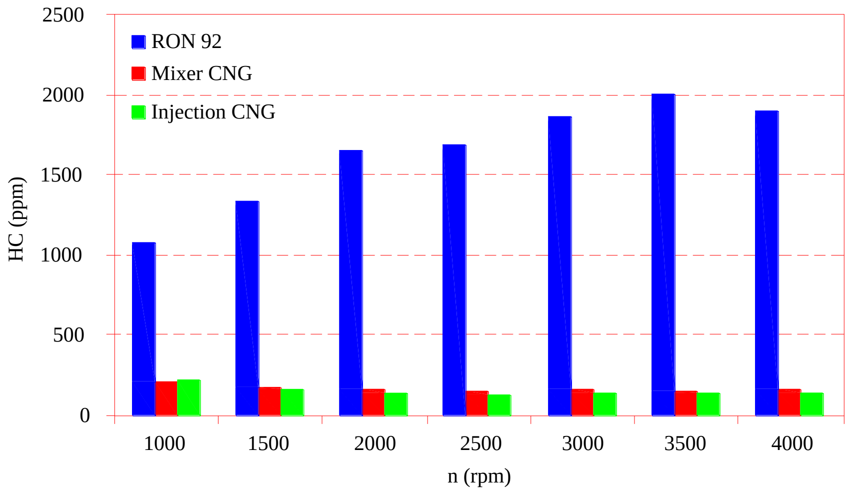

Figure 8 HC emission at full load at different speeds when the engine is running gasoline RON 92, CNG mixer, CNG injection

The result of the measurement of HC emission at full load modes on the external characteristic line of the engine was shown in Figure 8. The results showed that CNG engines reduced the HC emissions from 79% ÷ 93%, 86% on average when using RON 92 gas over the whole speed range.

At different loading modes at 3000rpm (figure 8), HC emissions of CNG engines is reduced to compare to engine emissions used RON 92 gasoline from 71% to 93%, averaging 82%. The HC emissions of CNG injection engines have improved compared to CNG engines using the mixer but not much improvement from 10% to 18%.

NOx emission

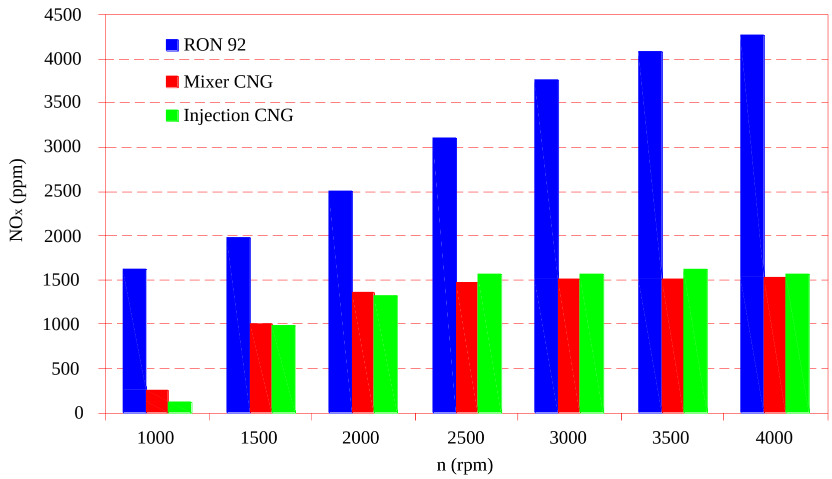

Figure 9 NOx emissions at full load at different speeds using RON 92 CNG mixer, CNG injection

Figure 9 shows and demonstrates the NOx emission measurement results of the engine at constant speed and load modes on the outgoing line and the load characteristics of the engine when using RON 92 gasoline, CNG with mixer, CNG sprayer. Data from tables and graphs shows that the CNG NOx emissions with or without additive additives are considerably reduced compared to engines with gasoline. NOx reductions range from 42% to 60%, with an average reduction of about 51%. It is possible to explain why the reduction of NOx emissions is due to the lower rate of fire spread of CNG than gasoline, so the slower burning process increases the heat loss through the wall of the cylinder resulting in reduced temperature. In addition, CNG has a lower membrane temperature of gasoline fuel and has a higher octane value than gasoline, so the longer fire retardation also reduces the combustion temperature. All of these factors result in reduced combustion temperatures, which in turn reduce NOx emissions. The NO emissions of CNG injection engines is increased form 3% to 16% compared to CNG engines using the mixer.

5. CONCLUSION

The study has calculated the design of CNG equipment using the mixer and CNG spraying equipment to ensure easy installation and adjustment to meet the requirements of work and ensure reliability.

+ CNG supplying system with low cost mixer, simple installation and adjustment process, can be installed for all types of gasoline engines. However, the engine conversion performance is worse than using CNG injection system should only be used when difficult to equip the CNG injection system.

+ CNG injection system is designed to take full advantage of the equipments of the gasoline injection system. As a result, it is simple and can be easily installed on the electronic gasoline injection engine to switch to use CNG. The system improves the power and fuel consumption of the engine than using the mixer.

After researching gasoline engine tests using CNG, the results show the effects of CNG-granting methods on power, fuel consumption and emissions of CO, HC, NOx components of the engine. In particular, when using CNG, the power the engine was reduced by 20.8% in the case of blenders, a decrease of 15.9% in the case of injection systems, but the fuel consumption decreased by 2.4% and 3.1% respectively, when using these two gas supply systems. CO and HC emissions decreased by 85% and NOx by 58%.

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