Studying Simultaneous Injection of Natural Gas and Gasoline Effect on Dual Fuel Engine Performance and Emissions

A. Mirmohamadi, SH. Alyari shoreh deli and A.kalhor

1-Department of Mechanical Engineering, Shahid Rajaee Teacher Training University, Tehran, Iran 2-MSc in Mechanical Engineering – Power train, Shahid Rajaee Teacher Training University, Tehran, Iran

Abstract

According to the Global Fuel Crisis, it seems necessary to use alternative fuel instead of gasoline. Since the natural gas is cheaper, have higher frequency than gasoline and less pollution, it is a suitable fuel. Many efforts have been done in order to replace gasoline with natural gas. One of the methods is to inject natural gas and gasoline fuel simultaneously and to use the benefits of both fuels. The purpose of this paper is studying natural gas and gasoline blend effect on engine power, torque and emissions. The simulated model was validated in different engine RPMs for gasoline and natural gas, were separately injected into the engine at full load condition. The results of simulation was had good agreement with experiments. The results show that by natural gas and gasoline Simultaneous injection power and torque have been reduced. NOX, HC and CO2 Pollutants change periodically, but their production level is generally lower than gasoline mode, but the CO pollutant increases.

***Keywords**: Mixture Gas and gasoline, Simultaneous injection, simulation, Engine Performance.*

1. Introduction

Started in 1381 in Iran KHODRO Company. Now it's a strategic and inexpensive engine produced in the company. This Engine is used in Peugeot Pars, Samand and Peugeot 405 products. The main challenge facing this engine and other useful engines is to replace gasoline with other clean fuels for lower pollution and fuel consumption. Natural gas combustion temperature is higher than gasoline then it increases NOX pollutant and reduces the useful life of engine parts also occupies a large volume of gas in the runner reduce engine volumetric efficiency. By injecting both gas and gasoline fuels simultaneously, can benefit from the advantages of both fuels and reduce the disadvantages of each of the fuels significantly. The simultaneous utilization of natural gas and gasoline causes reduction in pollutions, increase in power and torque of the engine towards a condition that the natural gas is used as fuel alone. Understanding the effects of mixed gasoline and gas combustion simultaneously requires an empirical test but due to its costly and time-consuming feature, in the early stages can use the computer simulation to investigate it. By validating the simulation results with help of experimental data from tests, the data obtained can be generalized to the different fuel conditions.

2. History of research

Vivien et al carried out simultaneous methane and petrol injection test on the Renault Company F4RT engine and they reached more braking torque than gasoline or gas injection mode separately [1]. Ebi Yols and his colleagues accomplished the simultaneous methane and petrol injection test on a 1.6-liter turbocharged direct injection engine. Its result is low specific fuel consumption and low THC pollutant [2]. Pipitone and his colleagues carried out a natural gas and gasoline injection test with a different sprinkle strategy to improve the performance of gas engine and achieved better performance [3]. Michel Robert and his colleagues fulfilled sprinkle Plan of 3 types of fuel including gasoline, ethanol and natural gas on the vehicle and in addition to increased power, they were able to decrease the cost of fuel economically in 1 year [4]. Pishgui use of variable valve timing system in with simulation XU7 engine using GT-Power software and his results shows less brake specific fuel consumption for engine[5]. Kasraie used GT-POWER software for the simulation of XU7 internal combustion engine [6]. Riahi used GT-POWER software for the simulation of B5 internal combustion engine [7]. Kakaei used GT-POWER software for simulation and Optimization of the Input runner in XU7 engine [8].

The purpose of this research is studying different natural gas and gasoline mass fraction effect on power, torque and exhaust emission of XU7 engine by GT-POWER software.

3. Engine modeling

Table 1 and Table 2 shows engine and natural gas specifications respectively.

In this study, the percentage of gasoline and natural gas blend was varied from 0% to 100%. details of these percentages separately as a new fuel injected through an injector in the intake runner and this fuel effect on power, torque and emissions are evaluated and compared with pure gasoline and natural gas fuel one.

Weib function is used for combustion modeling [8]. For this purpose, two parameters are needed:

1. Crank angle between the TDC and completed 50% of combustion, this parameter is generally 5 to 12 degrees.

2. Crank angle between 50% and 90% complete combustion, this parameter is generally 25 to 35 degrees.

Combustion model is two-zone temperature and other properties for both burned and unburned area is calculated independently.

The following equation is fuel injected models. Injection time is between 180 to 210 degrees of crankshaft rotation lasts.

$$M_{delivery} = \eta_v N_{rpm} V_d (F/A) \frac{6}{(\# CVL)(Plusewidth)}$$

Heat transfer rate in the cylinder is calculated using woschni model. Heat transfer coefficient calculated using the following equation as a woschni function:

$$Hg = 3.2B^{-0.2} P_r^{0.8} T_r^{0.53} V_c^{0.8}$$

$$V_c = C_1 V_m + C_2 \frac{V_d T_{r1}}{P_{r1} V_{r1}} (P_r - P_{mot}) \quad (8)$$

In the above equation in the suction and discharge:

$$C_1 = 6.18 + 0.417(\frac{V_s}{V_m})$$

The compression and expansion:

$$C_1 = 2.28 + 0..308(\frac{V_s}{V_m})$$

Dalton model was used to combine the two fuels

Table 1. General specification of test engine

parametr	value
No. of cylinder	4
Type of engine	In line
Bore	83 (mm)
Stroke	81.4 (mm)
Con rod	150.5 (mm)
Ignition order	1 – 3 – 4 – 2
Engine volume	1761(cc)
Compression ratio	9.3:1
fuel	gasoline -CNG
Max power in gasoline mode	70.8(Kw)@6000
Max torque in gasoline mode	153.4(N-m)@2500
Max power in CNG mode	56.7kW @6000rpm
Max torque in CNG mode	131.2Nm @2400rpm
No. of valve	8
Fuel system	MPFI

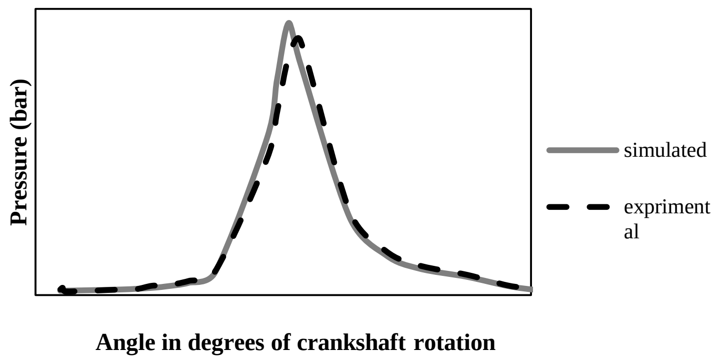

Fig 1.pressure in the cylinder according to the angle of rotation of the crankshaft in gasoline injection [12]

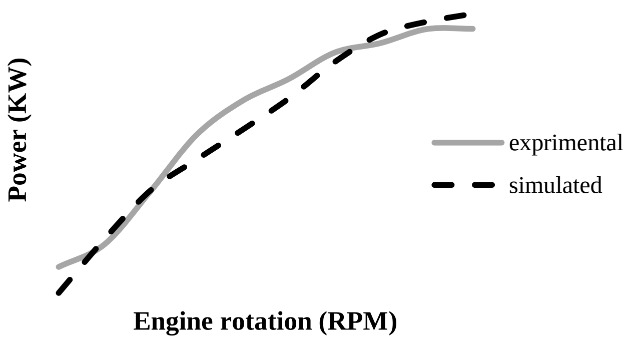

Fig2. Changes in engine power compared to engine speed in gasoline injection [12]

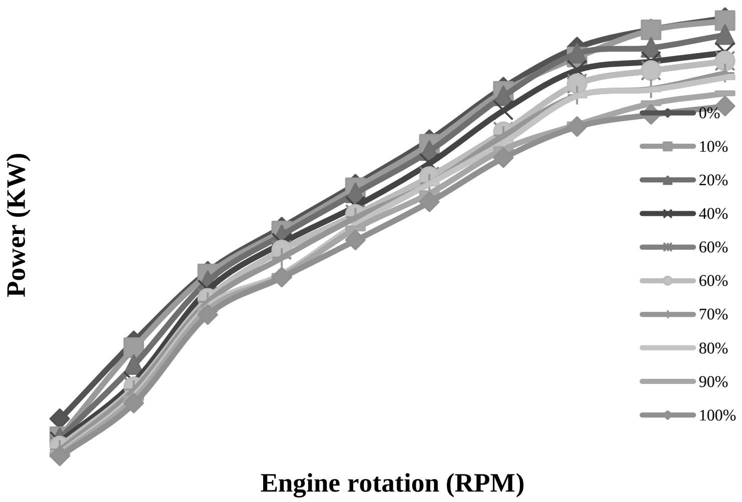

Fig 3. Changes of engine power to the engine speed at different percentages of natural gas injection

3. Model

3-1.Verification of model

To investigate the effect of gas injection in to gasoline engine, research is needed to build a reliable model. In this study, the engine model was simulated in GT-POWER software. To verify the results of the simulation, gasoline fuel injected into the engine and the results were compared with experimental results. To ensure the accuracy of the results of the simulation model results gasoline injection and injection of natural gas in 3000 RPM were compared with experimental results. Experimental data's was provided from IPCO Company. The base engine is a gasoline XU7engine and its data's are used to verify the results at 3000 RPM in gasoline injection mode. All results are in full load.

The pressure simulation results were shown in Figure 1 in comparison with experimental results. We see that the difference is about 8%. Indicated that among the reasons for this difference, regardless of the passage of the crankcase gases into the combustion chamber. The main assumptions in the simulation include:

1. Passes through the crankcase gases are negligible.

2. Air-fuel mixture is homogenous at the moment of closing the inlet valve.

3-2. Simulation results

3-2-1. natural gas injection effect on engine performance

Mass percent of natural gas in the mixture of natural gas and gasoline from zero to 100 percent, at full load conditions change and changes in power, torque and emissions have been assessed Changes in engine speed showed in Figure 3.

Engine torque - speed in different mass percentages of natural gas have been shown in figure 4. It has been seen that engine torque is reduced with increasing natural gas injection due to reduced volume and lower flame speed range.

3-2-2. Natural gas injection effect on engine emissions

NOX emissions from the engine exhaust gas have been shown in Figure 5. By injection of gas into a mixture of gasoline and air NOX pollutant are oscillatory changes in such a way that at first declined and then increased again decreased. In general it can be said that higher gas injected into the mix NOX emissions are generally decreasing trend show. According to the chart, the maximum NOX occurs in 40 percent of the natural gas injection and then decline sharply to 100 percent so that the least amount of NOX in the case of natural gas injection occurs.

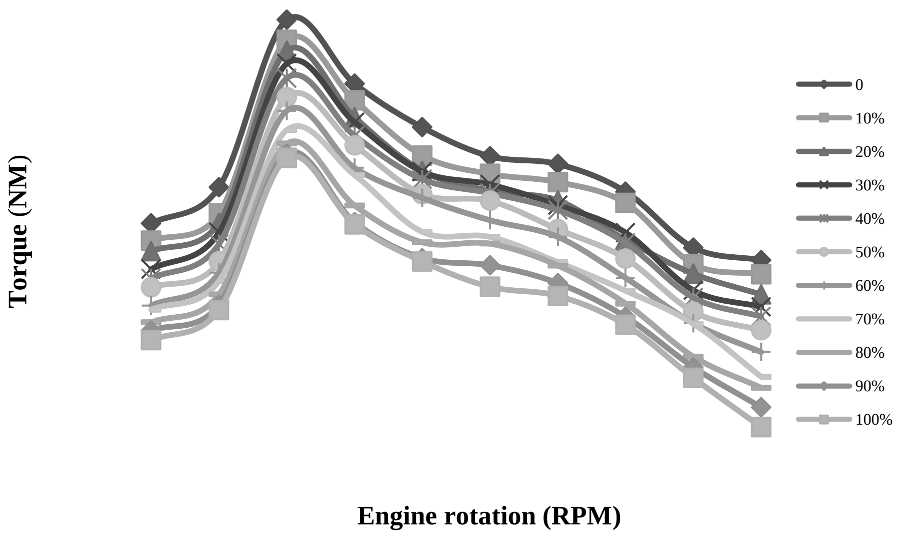

Fig 4. Changes of engine torque to the engine speed at different percentages of natural gas injection

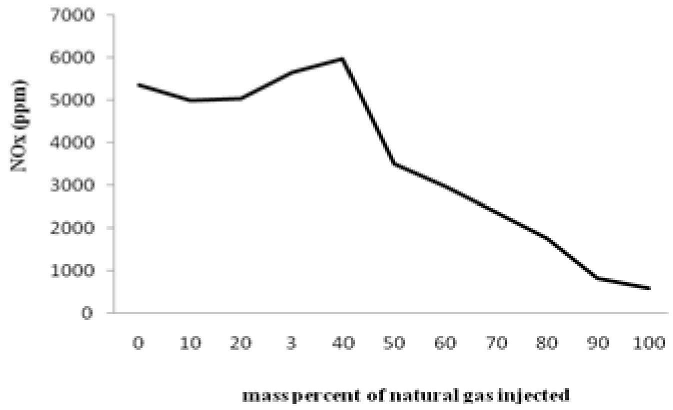

Fig5. Changes of NOX emissions based on the percentage of natural gas injection

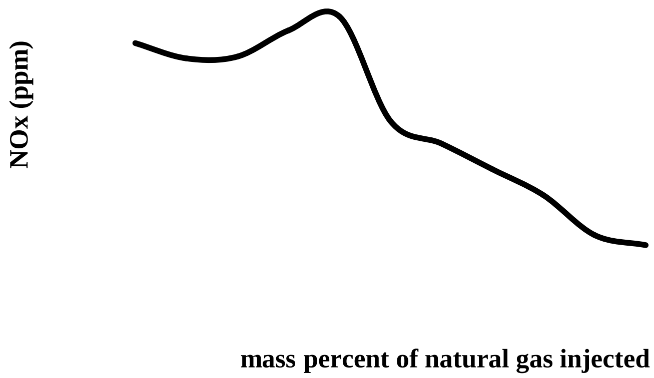

Fig 6. Changes in carbon dioxide emissions based on the percentage of natural gas injection

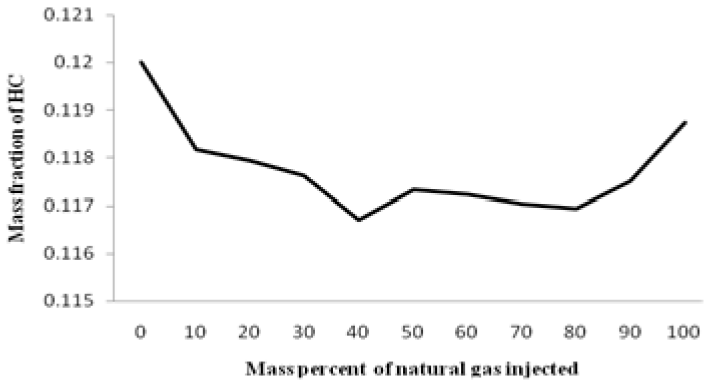

Fig 7. Changes in HC emissions based on the percentage of natural gas injection

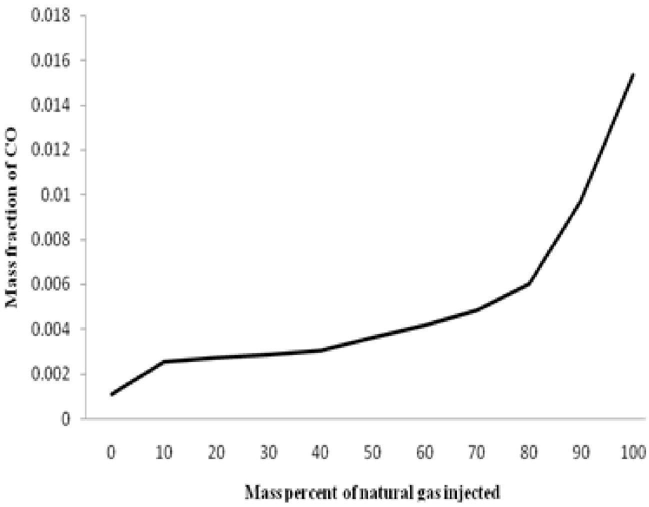

Fig 8. Changes in CO emissions based on the percentage of natural gas injection

Figure 6 shows emissions of carbon dioxide varying by natural gas injection. We are seen that carbon dioxide emissions first increased slightly and then decreased because of volumetric efficiency decreasing by more gas injection. First, because of the low ratio of carbon to hydrogen gas by increasing the percentage of natural gas carbon molecules involved in chemical reactions burning reduced. With the percentage of natural gas injection into gasoline decreased *volumetric efficiency and thus reduces the amount* of oxygen. This will reduce CO2 emissions. This can be seen from figure 7 that is increased

unburned hydrocarbons in the lake of oxygen required for the complete combustion.

Figure 7 shows HC emissions as injection of natural gas. First, because of the low ratio of carbon to hydrogen gas by increasing the percentage of natural gas reduce emissions of HC. HC produced due to the reduction in volumetric efficiency and a lack of enough oxygen to burn completely. Lack of oxygen prevents complete combustion of hydrocarbons will increase the emissions of HC . Minimum amount of HC emission is in 40% natural gas injection.

Figure 8 shows CO emissions as injection of natural gas. CO produced due to the reduction in volumetric efficiency and a lack of enough oxygen to burn completely. By increasing the mass percentage of natural gas injected into the engine, because it reduces the volume range and thus reduces the oxygen, producing CO increases. First, due to the reduction of carbon to hydrogen CO slow the rise in emissions will rise, but with the percentage of gas injected into the gasoline production process increases.

4. Conclusion

The study presents a solution to Replacement through the simultaneous use of CNG and gasoline as alternative fuel.

When converting to CNG, the main goal is economic and reduction of environmental pollution. However, when this economy and reduction of environmental pollution generates significant power loss, this may discourage the use of CNG.

Compared to gasoline fuel, using combined fuel would reduce the number of pollutants. This occurs because Chemical structure of synthetic fuel, gasoline is different.

The initial power on gasoline is about 70.8 KW. But with the percentage of natural gas injected into the gas reaches the value of 56.7 KW.

With the proposed fuel, can be used to take advantage of both fuels simultaneously, and flexibility in power, torque and pollutants.

References

[1]. V. Delpech, J. Obiols and D. Soleri , L. Mispreuve, E. Magere and S. Kermarrec., “Towards an Innovative Combination of Natural Gas and Liquid Fuel Injection in Spark Ignition Engines”, SAE International: (2010).

[2]. Obiols, D.e Soleri , N. Dioc, M. Moreau., “Potential of Concomitant Injection of CNG and Gasoline on a 1.6L Gasoline Direct Injection Turbocharged Engine”, JSAE: (2011).

[3]. E. Pipitone, S. Beccari., “Performances improvement of a s.i. cng bi-fuel injection”, SAE International: (2011).

[4]. M. R. Veiga , R. D. Masano , R. L. Silva , C. W. Gomes., “Injection system for tri-fuel engines with control of power by simultaneous use of CNG and ethanol or gasoline”, SAE International: (2010).

[5]. M. Pishgooie , “studying the effect of using turbocharger in design and performance of CNG engines”, MSC thesis Iran University of science and technology . (2010).

[6]. R. Kasrai., “Samand engine manifold modeling and optimization” , MSC thesis Iran University of science and technology . (2006).

[7]. M. ebrahim a., “studying the effect of using turbocharger in design and performance of CNG engines” , MSC thesis Iran University of science and technology . (2007).

[8]. A. Riahi., “Modeling and Performance Analysis of an Internal Combustion Engine by GT-Suite” , MSC thesis Iran University of Shahid Rajaee Teacher Training University. (2014).

[9]. M. Ameri, F. Kiaahmadi, M.r Khanaki., “Comparative analysis of the performance of a dual-fuel internal combustion”, JOURNAL OF POWER TECHNOLOGIES, Vol 92, No 4: (2012)

[10]. M. Ameri, F. Kiaahmadi, M.r Khanaki., “The Effect of Using Variable Valve System on XU7/L3 intake system, With the aim of increasing the volumetric efficiency”, The Journal of Engine Research, Vol 21, No 21: (2010)

[11]. G. J.Vanvilen, Fundamentals of Thermodynamics, 5nd ed.

[12]. Performance XU7 engine with Gasoline fuel , EPCO Company

List of symbols			
CO	Carbon monoxide emissions (mass fraction)	**B**	Bore (mm)
CO_2	Carbon dioxide emissions (mass fraction)	V_d	Cylinder displacement volume (m^3)
HC	Emissions of unburned hydrocarbons (mass fraction)	P_{mot}	Cylinder pressure in the engine case handling (kpa)
N	engine Rotate Speed (RPM)	V_s	The linear velocity of the piston (m/s)
NO_X	Nitrogen oxides emissions (PPM)	T_r	Reference temperature (0ºc)
P	Power (KW)	P_{mot}	Cylinder pressure in the engine case handling (kpa)
T	Torque (N.M)	V_s	The linear velocity of the piston(m/s)
$Vr,1$	volume when Inlet valve close (m^3)	P_{mot}	Cylinder pressure in the engine case handling (kpa)
$Tr,1$	Temperature when Inlet valve close (ºk)	V_s	The linear velocity of the piston (m/s)
$Pr,1$	Pressure when Inlet valve close (kpa)	**CNG**	Compressed natural gas
P_r	Reference pressure (1bar)	**Greek Symbols**	
T_r	Reference temperature (0ºc) η_v		Volumetric efficiency (m^3/s)
$M_{delivery}$	Relivered mass (kg)		