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AVL Boost Simulation of Engine Performance and Emission for Compressed Natural Gas Direct Injection Engine

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KEYWORDS

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CNGDI
CNG Vehicle

ABSTRACT

Natural gas is an alternative to gasoline as a fuel for automotive engines. The combustion of natural gas produces mainly water and CO_2 and significantly less CO and UHC emissions. In many cases, CNG vehicles generate fewer exhaust and greenhouse gas emissions than their gasoline or diesel-powered counterparts. Internal combustion engines can be powered by natural gas without significant effort in production and distribution since raw natural gas needs minimal processing before distribution. In this research, a study of direct injected CNG engine is conducted. AVL Boost was used to simulate methane direct injection, CNG port injection and gasoline port injection in a four-cylinder spark ignition engine. Methane is used in place of CNG for simplicity. There appears to be a good approximation from initial tests since CNG comprise around 80-90% methane.

1. INTRODUCTION

Natural gas is one of the most widely used forms of energy today. Natural gas has been recognized as a leading candidate as an alternative fuel in internal combustion engines in the near future. It is hoped that natural gas will widely substitute conventional fuel such as gasoline and diesel for reduced emissions, low cost and richness of resource. To use natural gas, engines must be designed to have a suitable combustion system [1].

The combustion of natural gas produces mainly water and CO_2 and significantly less CO and UHC emissions. In many cases, CNG vehicles generate fewer exhaust and greenhouse gas emissions than their gasoline or diesel-powered counterparts. Internal combustion engines can be powered by natural gas without significant effort in production and distribution since raw natural gas needs minimal processing before distribution [2].

The objective of this research is to compare engine performance of different fuel injection system on a simulation engine performance. In this research, the study of the natural gas vehicles for the improvement of natural gas converted engines by direct injection is being done. When a gasoline or diesel engine is converted directly to use CNG, natural gas and air is mixed in the intake manifold. As a result the engine power is reduced and the upper speed restricted [3]. Direct injection can mitigate these by injecting fuel after the intake valve is closed. Thus, the cylinder receives the maximum possible mass of air [4].

AVL Boost was used to simulate and calculate the performance of methane direct injection, CNG port injection and gasoline port injection in a four-cylinder spark ignition engine. AVL BOOST simulates a wide variety of engines, 4-stroke or 2-stroke, spark or auto-ignited [5].

2. NATURAL GAS

Natural gas occurs in reservoirs beneath the surface of the earth. It is tapped either by itself or along with crude oil from underground. The annual worldwide production is almost 2 billion tonnes of oil equivalent or t.o.e ($1000m^3$ = 0.85 t.o.e) in the last years of the 20^{th} century [6].

Natural Gas is a vital component of the world's supply of energy. It is one of the cleanest, safest, and most useful of all energy sources. Despite its importance, however, there are many misconceptions about natural gas. Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane and pentane [7].

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3. SIMULATION

Simulation is done to compare the performance of port injected gasoline, port injected CNG and direct injected CNG. Assumptions were made that there is perfect mixture in the combustion chamber and the CNG properties are similar to methane. **Table 1** shows some of the important parameters of the engine.

Table 1. Engine parameters

Parameter	Gasoline Port Injection (G-PI)	CNG-Direct Injection (DI)
Bore	76 mm	76
Stroke	88 mm	88
Compression ratio	10	10
Inhaled air	100Kpa@298K	100Kpa@293K
Start of Combustion (BTDC)	-5	-10

Table 2. Simulation results at different start of combustion of CNG DI

Start of Combustion	Power	Torque
-10	63.51	151.62
-12	63.51	151.61
-15	63.22	150.92

Table 2 shows that the optimum output for CNG DI was achieved when combustion starts at -10 degree BTDC.

4. COMPARISON RESULTS

The result of the simulation is shown in **Fig.1-3**. Three sets of data are shown representing port injection gasoline (G-PI), port injection CNG (CNG-DI) and direct injection CNG (CNG-DI) engines. Power, torque and volumetric efficiency curves of direct injection of CNG results show better performance than port injection of CNG and comparable with gasoline port injection. At higher RPM, CNG-DI gives higher torque, power and volumetric efficiency. This shows that the CNG-DI system is a viable alternative to port injection gasoline system.

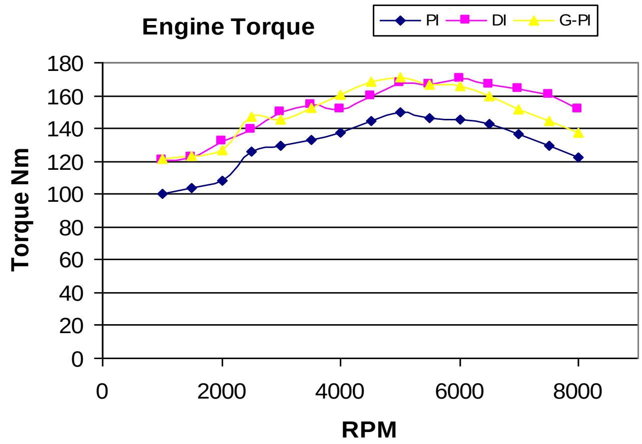

Fig.1. Engine torque against RPM

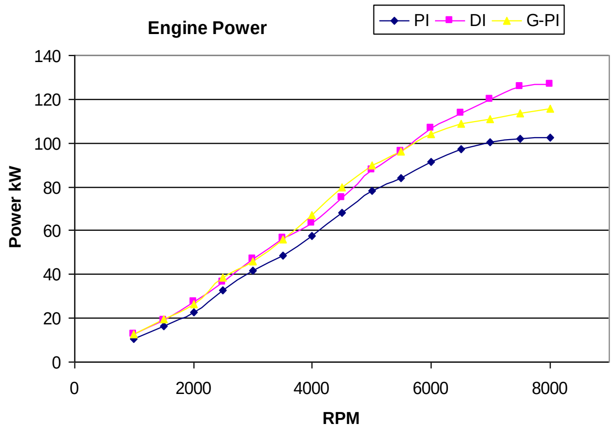

Fig.2. Engine power against RPM

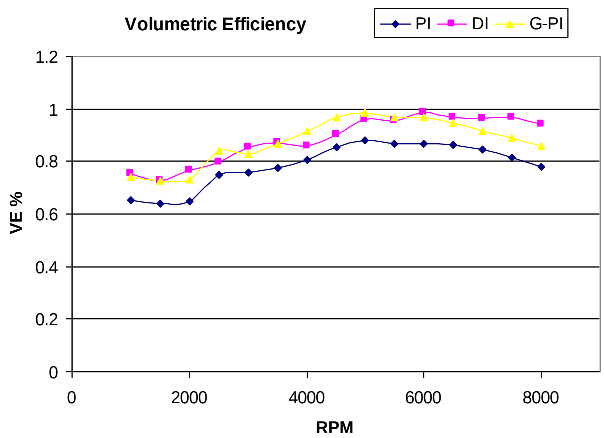

Fig.3.Vol eff against RPM

Pressure trace against crank angle in **Fig.4** show higher pressure achieved with Methane (major constituent of CNG) Direct Injection, Moreover temperature trace against Crank Angle in **Fig.5** show higher temperature achieved with methane direct injection which may lead to higher NO_x. For future work, the spark timing can be varied to reduce maximum temperature thus in turn reducing potential NO_x being produced.

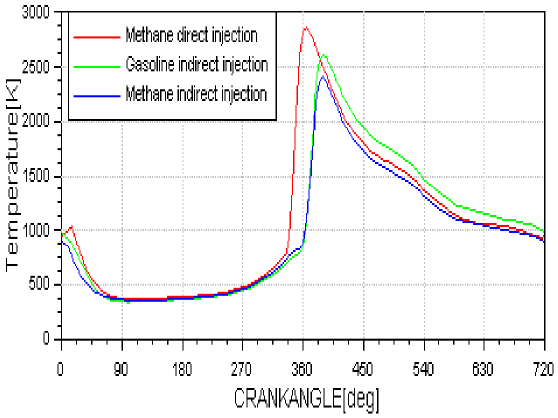

Fig.4. Pressure against Crank angle

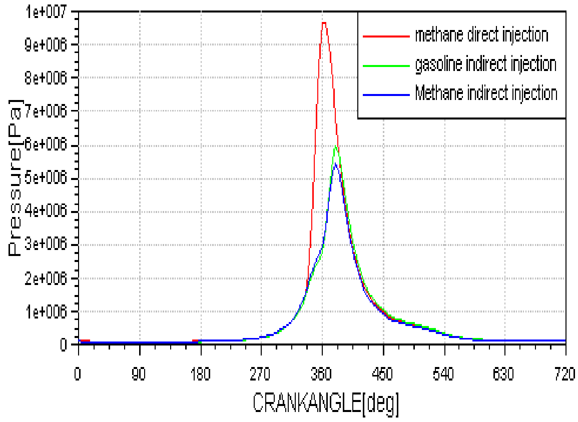

Fig.5. Temp against Crank angle

5. CONCLUSIONS

CNG as an automotive fuel is one of the solutions to lower emission of CO_2 into atmosphere. Converting gasoline to CNG in port-injected engine could result in reduced peak power and limited engine speed. Direct injection of CNG can mitigate this by injecting CNG into the combustion chamber after the intake valve is closed. Simulations have verified that peak power closer to gasoline engine can be achieved.

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