Comparison of Engine Performance for Diesel and CNG Fuel Using GT-Power Software

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Abstract — Study on simulation of 4-stroke single cylinder engine is being presented. The engine with known specification is being modelled using one dimensional CFD GT-Power software. The same engine is used for different fuel; diesel and CNG. The operational parameters of the engine such as brake power, brake torque and brake specific fuel consumption which are dependent to engine speed are discussed. The results of engine performance from diesel and CNG fuel are compared to get the percentage of reductions.

Keywords: GT-power, computational modelling, 4-stroke DI diesel engine, CNG.

INTRODUCTION

Natural gas has been used as an alternative fuel widely in internal combustion engine. This is because of current market price for crude oil has increased rapidly. Natural gas produces very low pollution [1,4,5] compared to diesel and gasoline. One main problem that hinders the mass implementation of CNG fuelled vehicle in the market nowadays is its low power output due to losses in volumetric efficiency, low flame speed and absence of fuel evaporation [2] which only has a range of 40% - 50% gasoline engine power output [3].

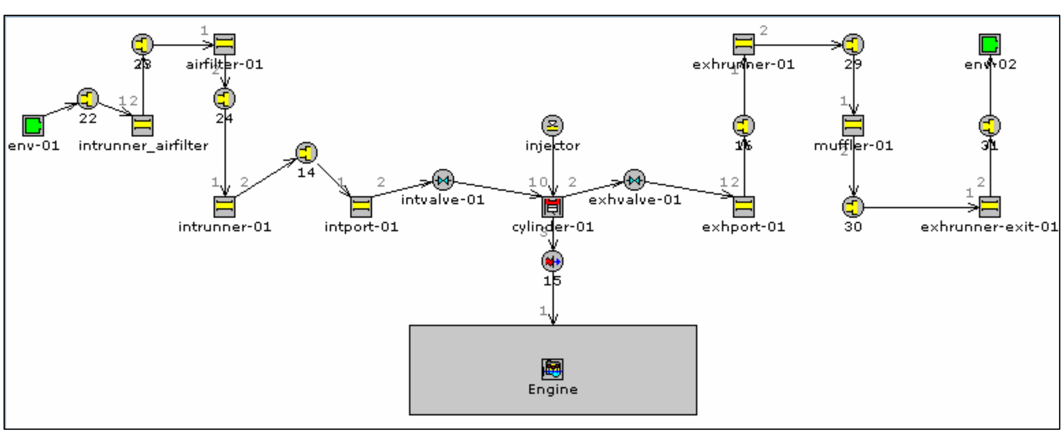
In this research, the engine performance parameters such as power, torque and mean effective pressure are studied when using diesel and CNG as fuel. A one dimensional CFD GT-Power software has been used to simulate the engine model and to analyse the required parameters. The advantages of one dimensional CFD program compared to three dimensional program are fast computation, high flexibility, adaptability of the model for the complete range of engine operation points [6]. The simulation method is chosen because workstations are more cheaper than test benches.

MODELLING METHODOLOGY

In this research the computer simulation method using GT Power is used. The engine specification is shown in Table 1. This engine being modelled in GT Power software is shown in Figure 1. Two types of fuel will be used; diesel and natural gas. These fuels will be used at different simulation.

TABLE 1
ENGINE SPECIFICATION

Item	Technical Specification
Type	Single cylinder, vertical, air-cooled, direct injection, 4 stroke
Bore (mm)	86
Stroke (mm)	70
Displacement (L)	0.406
Initial angle of fuel delivery (CA)	-22º ± 1º BTDC
Intake valve clearance (mm)	0.1~0.15 (cold state)
Exhaust valve clearance (mm)	0.1~0.15 (cold state)
Exhaust temperature (ºC)	≤ 480
Pressure of injection (MPa)	≤ 19.6 ± 0.49
Mean effective pressure (kPa)	561.6 @ 3000 rpm 543.5 @ 3600 rpm
Consumption rate of fuel (g/kW)	≤ 273.5 @ 3000 rpm ≤285.7 @ 3600 rpm



Air with compositions of 76.7% N_2 and 23.3% O_2 at pressure 1 bar and temperature 26.85ºC is being modelled as env-01. The properties for env-02 are similar with env-01. The intake system consists of intrunner_airfilter (intake runner for air filter), airfilter-01 (airfilter box), intrunner-01 (intake runner) and intport-01 (intake port). These parts represent the pipes with specific parameters as shown in Table 2. The exhaust system consists of exhport-01 (exhaust port), exhrunner-01 (exhaust runner), muffler-01 (muffler) and exhrunner-exit-01 (exhaust tail). These parts also represent the pipes with specific parameters as shown in Table 3.

Intvalve-01 represents intake valve and exhvalve-01 represents exhaust valve. The parameters of these valves are shown in Table 4.

TABLE 2
PARAMETERS FOR INTAKE SYSTEM

	Intrunner _airfilter	Airfilter-01	Intrunner-01	Intport-01
Diameter at inlet end (mm)	44.88	159.632	40.44	40.6973
Diameter at outlet end (mm)	62.13	159.632	40.1	32.78
Length (mm)	80	69.64	59.7	55.2
Discreatization length (mm)	34.4	34.4	34.4	34.4
Wall temperature (ºC)	28.85	28.85	76.85	176.85

TABLE 3
PARAMETERS FOR EXHAUST SYSTEM

	exhport-01	exhrunner-01	Muffler-01	exhrunner-exit-01
Diameter at inlet end (mm)	26.38	27.86	138.88	34.6
Diameter at outlet end (mm)	29.82	27.86	138.88	34.6
Length (mm)	40.4	98	283.4	25.6
Discreatization length (mm)	47.3	47.3	47.3	47.3
Wall temperature (ºC)	480	480	480	480

TABLE 4
PARAMETERS FOR INTAKE AND EXHAUST VALVES

	Intvalve-01	Exhvalve-01
Valve diameter (mm)	35.54	29.04
CAM timing angle (ºCA)	462.5	214.6
Valve lash (mm)	0.125	0.125

Results and Discussion

The simulation results for comparison between diesel and CNG fuel are shown in Figure 2, 3 and 4. Figure 2 shows that when diesel fuel is being used ,the brake power changes from 0.09kW at 200 rpm to 2kW at 4000 rpm. The peak value is 4.3kW at 3000 rpm which is the maximum brake power for diesel fuel. Meanwhile when CNG fuel is being used the brake power changes from 0.04 kW at 200 rpm to 2.4kW at 4000 rpm. The maximum brake power for CNG fuel is 2.4kW at 4000 rpm. By comparison, the maximum brake power will reduce 44% when using CNG as fuel.

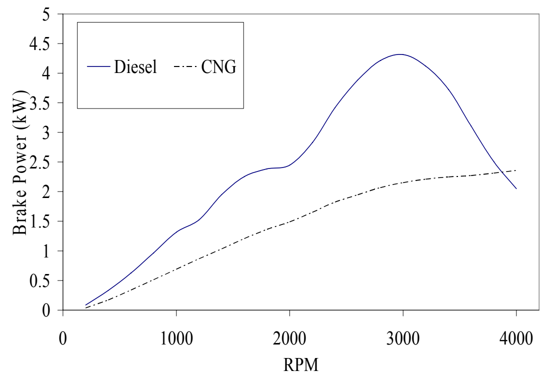


Fig. 2. Comparison between diesel and CNG fuel for brake power.

Brake torque versus rpm graph is shown in Figure 3. For diesel fuel, the brake torque changes from 4 Nm at 200 rpm to 4.9 Nm at 4000 rpm. There are three peak values; 12.6 Nm at 1000 rpm, 13.5 Nm at 1500 rpm and 14.4 Nm at 2700 rpm. The maximum brake torque is 14.4 Nm at 2700 rpm. Meanwhile, for CNG fuel, the brake torque changes from 1.7 Nm at 200 rpm to 5.6 Nm at 4000 rpm. The maximum brake torque for this fuel is 7.3 Nm at 2400 rpm. By comparison, the maximum brake torque will reduce by 49 % when using CNG as fuel.

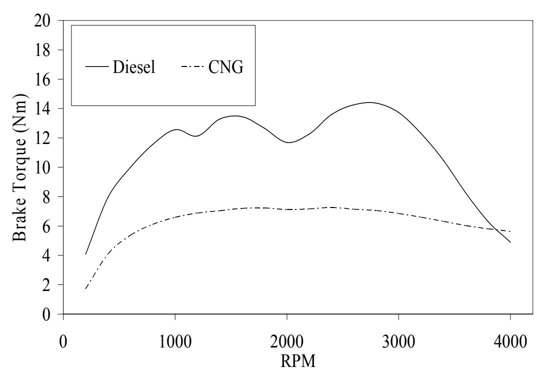


Fig. 3. Comparison between diesel and CNG fuel for brake torque.

The comparison of brake specific fuel consumption for diesel and CNG is shown in Figure 4. For diesel fuel, the brake specific fuel consumption changes from 1232 g/kWh at 200 rpm to 1025 g/kWh at 4000 rpm. The minimum brake specific fuel for diesel fuel is 349 g/kWh at 2800 rpm. Meanwhile, for CNG fuel, the brake specific fuel consumption changes from 2940 g/kWh at 200 rpm to 891 g/kWh at 4000 rpm. The minimum value for this fuel is 691 g/kWh at 2400 rpm. By comparison, the minimum brake specific fuel consumption will increase 49 % when using CNG as fuel.

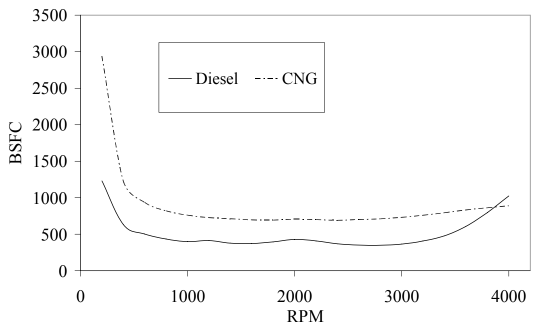


Fig. 4. Comparison between diesel and CNG fuel for brake specific fuel consumption.

The usage of CNG in the small diesel engine will increase brake specific fuel consumption and reduction in terms of brake power and brake torque. This is because of gas fuel will reduce volumetric efficiency compared to liquid fuel as shown in Figure 5.

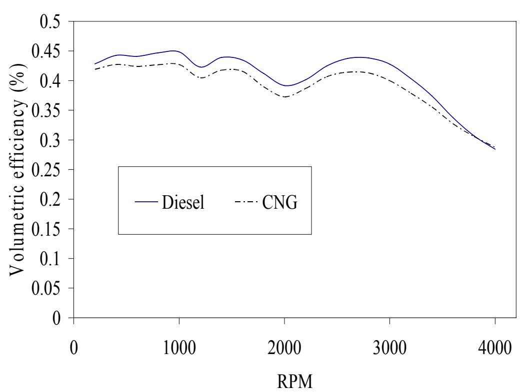


Fig. 5. Comparison between diesel and CNG for volumetric efficiency.

Another factor that must be considered is composition of hydrocarbon for each fuel. Diesel which have higher hydrocarbon compares to CNG will give more energy to the engine as shown in Figure 6 through Figure 8. At 1000 rpm ignition process will occur at 5.7 and 4.5 degree crank angle for diesel and CNG respectively. The effect from this combustion will cause diesel fuel generates pressure 81 bar compare to CNG that will generates 70 bar. The pressure reduction is 8% from diesel fuel pressure.

At 2000 rpm ignition process will occur at 5.7 and 5.5 degree crank angle for diesel and CNG respectively. The pressure that will be generated are 76 and 67 bar for diesel and CNG respectively as shown in Figure 7. The pressure reduction is 12% from diesel fuel pressure. Meanwhile at 3000 rpm, ignition process will occur at 6.2 and 5.1 degree crank angle for diesel and CNG respectively. The pressure that will be generated are 82 and 71 bar as shown in Figure 8. The pressure reduction is 13% from diesel fuel pressure.

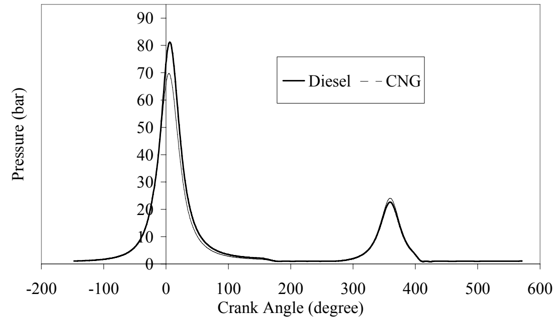


Fig. 6. Variation of pressure with crank angle at 1000 rpm

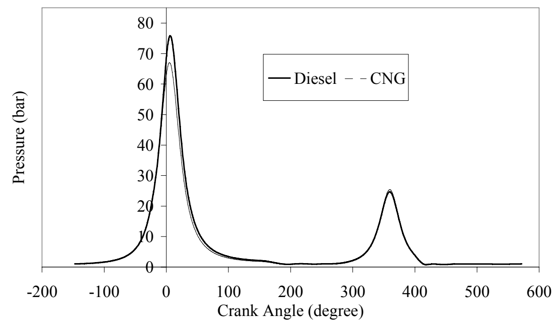


Fig. 7. Variation of pressure with crank angle at 2000 rpm

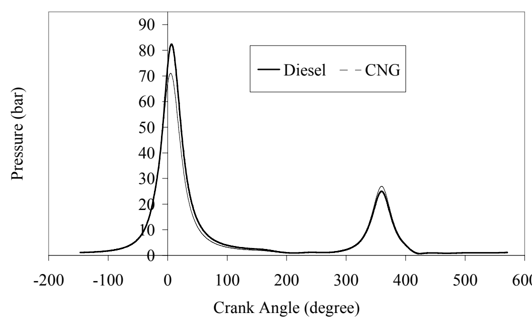


Fig. 8. Variation of pressure with crank angle at 3000 rpm

Conclusion

From these simulation studies, it is observed that CNG can be used as an alternative fuel into small diesel engine. The studied parameters show that there are reduction by 44% in brake power, 49% in brake torque and addition of 49% in brake specific fuel consumption. To ensure that the percentage can be reduced, the engine needs some modification. For further research, experimental study will be conducted to validate the simulation results and to reduce the percentages for the mentioned parameters.

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