# THE USE OF NATURAL GAS AS A FUEL FOR MOTORCYCLES

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## ABSTRACT

Utilization of motorcycle in Malaysia is really synonym especially for lower income group. Statistic for motor vehicles in Malaysia shown that nearly five million units or over the half are motorcycles. These are mostly small capacity, two or four stroke engine motorcycles. The use of low quality fuel to operate motorcycles causes a serious pollutant especially in densely populated areas. Besides, crude oil reserve in Malaysia is expected to finish within 19 years. Natural gas is now acknowledged by the world as being a mainstream alternative fuel. It has a high octane rating that is general indication of the ability of the fuel to burn more efficient and improving engine performance. Malaysia has massive, under exploited natural gas reserve. As such a study has been conducted by a group of researchers from Gas Technology Centre (GASTEG) to diversify the usage of natural gas especially as a fuel for internal combustion engine. The product of this research is a set of natural gas conversion kits and the first prototype of natural gas motorcycle. The exhaust emissions from natural gas motorcycle give complete combustion, which decrease 99.6% of carbon monoxide and 72.5% of unburned hydrocarbon at a speed of 70km/hr. However, the lower heat content of natural gas and the lower burning velocity as compared to gasoline reduces the engine maximum power for about 15% at high engine speed without any modification to the original engine. These parameters can be used as a guidance to the motorcycle industry how to utilise natural gas as a fuel, a new and a leading technology for the world that propelling Malaysia for the next millennium with clean city.

Key words : natural gas, natural gas transmission and distribution, natural gas vehicles, natural gas power motorcycle

## INTRODUCTION

Natural Gas is a colorless, odorless, fuel that burns cleaner than many other fossil fuels. Today, natural gas is being among of the most popular forms of energy and also has a fast gaining reputation as the "energy of the future".

Natural gas is produced, sometimes along with oil, by drilling into the Earth's crust where pockets of natural gas were trapped hundreds of thousands of years ago. Once the gas is brought to the surface, it is refined to remove impurities, like water, other gasses, and sand. Then it is transmitted through large pipelines that span the continent.

In Malaysia, natural gas is drilled from offshore Terengganu, Sabah and Sarawak while for gas utilisation in Peninsular Malaysia, natural gas from offshore Terengganu was piped to Kertih where it was treated in gas processing plants. These processed gases are then piped to the major consuming outlets in Peninsular Malaysia via the Peninsular Gas Utilisation (PGU) systems. PGU project which was develop by PETRONAS since 1984, now spans over 1700km comprising main gas transmission pipelines, supply pipelines and laterals.(Figure 1 )

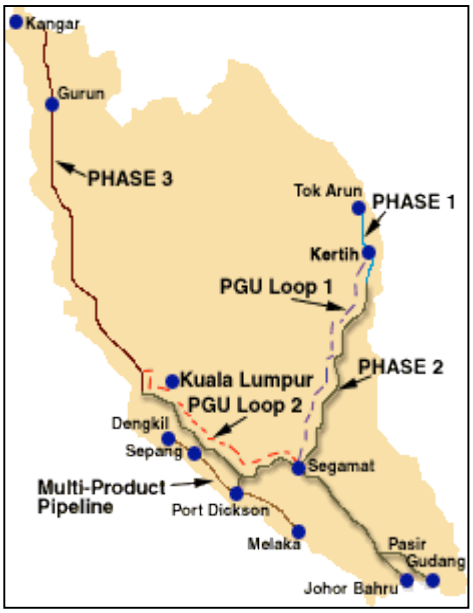


**Figure 1 : Peninsular Gas Utilisation (PGU) project (www.petronas.com.my)**

Prior to this, Gas Malaysia Sdn Bhd (GMSB) was the developer of Natural Gas Distribution System (NGDS) network for making gas available to the end-users. GMSB was incorporated in May 1992 and the only gas utility company in Peninsular Malaysia and was set-up to promote, construct and operate natural gas distribution system for the industrial, commercial and residential sectors. Up to July 2001, Gas Malaysia operates 476 kilometers of pipelines and another 166 kilometers of pipelines are under construction. (See Figure 2)

Proven reserves of natural gas are plentiful and have been steadily increasing over the last decades. Malaysia itself has the largest natural gas reserves among the Southeast Asian economies and is the third largest amongst the Asia Pacific economies. As at 1 January 2000, the recoverable reserves stand at 84.4 trillion standard cubic feet of which 48 % is located offshore Sarawak, 43 % offshore east coast of Peninsular Malaysia and the remaining 9 % offshore Sabah. Current national gas production at wellhead reached 4,951 mmscfd in 2000. Based on current gas production level, Malaysia's natural gas reserves are sufficient to last around 43 years.


**Figure 2. Natural Gas Distribution System (www.gasmalaysia.com)**

In the Malaysia, natural gas have wide acceptance due to its highly diversified utilisation in the various sectors of the economy. It is used for heating, cooling, power generation, combined heat and power production, fuel cells, natural gas vehicles (NGV) and it finds many uses in industry. Future gas demand by the power sector is expected to be maintained at around 60 % to 70 % of the generation mix. By 2005, 1,687 mmscfd of gas is expected to be used for electricity generation. The non-power sector accounted for 19.3% of total gas consumption in Peninsular Malaysia of which 45% was by petrochemical industry. The use of natural gas, to the extent of its availability, will bring more environmentally sustainable development and help to improve the quality of environment.

## NATURAL GAS AS A CLEAN FUEL

Natural gas is more environmentally attractive than other fossil fuels because it is composed chiefly of methane a molecule made up of one carbon atom and four hydrogen atoms. When methane is burned completely, the principal products of combustion are carbon dioxide and water vapor. In comparison, oil and coal compounds have much more complicated molecular structures. They include a higher ratio of carbon, as well as various sulfur and nitrogen compounds. They do not burn as cleanly. Coal and industrial fuel oil combustion also produces ash particles, which do not burn at all; however, they can be carried into the atmosphere. Because natural gas burns cleanly, its use can be an effective means of controlling pollution.

With the high price of gasoline and diesel fuel today, other fuels are being proposed as alternatives for vehicles use, as for example propane gas, solar energy, hydrogen, methanol, electric cars and etc. The only most suitable fuel for any mass conversion away from gasoline and diesel is natural gas. Increasing awareness for the environment also has encourage the use of cleaner burning natural gas as the fuel for internal combustion engines.

In Malaysia, where the supply of natural gas is in abundant, it is only logical to convert gasoline engines to use natural gas instead. Most conversion carried out to date is for gasoline fuelled public transport vehicles, in particular taxis, which can run on both natural gas and gasoline. Natural gas mainly consists of gas methane, which in its natural form is cleaner than gasoline, burns and emits naturally in cleaner way. Natural gas being a cleaner burning fuel, tends to prolong engine life due to lesser degradation of the engine oil as shown by the results of the engine oil study.

## DEVELOPMENT OF NATURAL GAS VEHICLES (NGV) IN MALAYSIA

The development of NGV in Malaysia began few years ago with a project of Natural Gas Vehicles pioneered by a small group taxi cars in Kuala Lumpur. This project is a success to Malaysia as developing country by participating along the energy consumption development in the world. PETRONAS was the leading organization to embark the development of natural gas vehicles in Malaysia. NGV started being used as a pilot program implemented by PETRONAS in 1986-1988 in Kertih, Terengganu. In 1991, PETRONAS implemented the Natural Gas for Vehicles Program (NGVP) in the high density Klang Valley area to coincide with the completion of the PGU II project. The PETRONAS NGV (PGNV) Sdn Bhd then was established on February 14, 1995 to spearhead promotion and development of NGV in Malaysia. With the vision “to be a leading NGV company of choice”, PGNV had built 22 NGV refueling station around Kuala Lumpur and Selangor. Their target is to construct 162 stations by the year 2006 in major cities in peninsular Malaysia capable of serving 160,000 vehicles. However, PGNV only introduced NGV system to taxis and heavy vehicles.

Malaysian government were aimed at reducing dependence on oil as an energy source and promoting the gas as a more efficient and clean-burning fuel to become the fuel of choice. Government provided incentives that show their dedication to the success

of this clean fuel policy. The incentives included setting the NGV retail pricing at 50% that of petrol and exempting retrofit kits from import duty and sales tax. At present, the retail price of NGV has to be done in phases to tie in with the operation of NGDS as it uses gas drawn from the Peninsular gas Utilistation's trunk line. Since 1992, government has set NGV's pump price at RM 0.565 per litre equivalent. In October 1st, 2000 other fuel was increased by 9% but there are no changes in NGV price. In addition, government also reduce of NGV road tax at 25-50% off.

Therefore, Universiti Teknologi Malaysia take a step further to introduced a NGV system for motorcycle. A group of researcher from Gas Technology Centre (GASTEG), Universiti Teknologi Malaysia, has succeeded in designing a motorcycle that can uses both gasoline and compressed natural gas (CNG) as a fuel. As part of the development program of Natural Gas Motorcycle (NGVM), a study on the lubrication effect from the combustion of both natural gas and gasoline has been carried out. The study as conducted to determine emission and performance of petrol-powered motorcycle and of natural gas powered motorcycle.

## NATURAL GAS POWER MOTORCYCLE

The development of the 4-stroke natural gas motorcycle prototype (specifications as listed in Table 1) can be divided into two main stages. The theoretical preparation and design stage and second stage is the procedure of testing and analysing. A whole new set of a conversion kit including a mixer in front of a carburetor, a regulator, control elements and measurement apparatus were designed. The compositional test on the content of natural gas used has been carried out at PETRONAS Gas Sdn. Bhd., Kerteh, Terengganu (Table 2). A series of test has been undertaken. As a result of performance test, the power outputs of the engine and exhausts emission data have been successfully recorded. From the test, a comparison was made between the emission and performance of petrol-powered motorcycle (petrol specification as listed in Table 3) and the natural gas powered motorcycle.

**Table 1 : MODENAS, KRISS 110 Specifications**

| | | |
|---|---|---|
| Type | Unit | 4 st, 1 cyl, SOHC |
| Bore x stroke | (mm) | 53.0 x 50.6 |
| Displacement | ($cm^3$) | 111 |
| Compression ratio | | 9.3 |
| Carburetor Type<br>Diameter of throttle valve | <br>Mm | KEIHIN PB18 X 1<br>18 |
| Diameter of venturi | Mm | 18 |
| Type of choke valve | | Butterfly |
| Lubrication system | | Forced lub. Wet |
| Engine oil Rating<br>Viscosity | <br>SAE Grade | SF OR SG<br>20W-40 |
| Capacity | (L) | 1.1 |
| Cooling system : Cooling method | | Air cooled |
| Ignition system | | Magneto to CDI |
| Ignition timing : Angle | ( $^o$/rpm) | 6.5 BTDC /1200 ~27 BTDC / 4000 |
| Spark plug : Type | | NGK C6HAS |
| Gap | Mm | 0.7 |
| Regularity | | C |
| Air cleaner Type<br>Number (qty) | | Wet element air filter<br>1 |

( Source: Modenas KRISS 110 Operating Manual)

**Table 2. Natural Gas Composition**

| Component | Mol % |
|---|---|
| $C_1$ | 93.07 |
| $C_2$ | 3.70 |
| $C_3$ | 0.90 |
| $iC_4$ | 0.29 |
| $nC_4$ | 0.13 |
| $iC_5$ | 0.07 |
| $C_{6+}$ | 0.07 |
| $CO_2$ | 1.10 |
| $N_2$ | 0.68 |
| | |
| Compressibility | 0.9977 |
| Density | 0.7404 $kg/sm^3$ |
| Relative Density | 0.6042 |
| Molecular Weight | 17.4663 |
| Gross Calorie Value | 39.20 $MJ/sm^3$ |

**Table 3: Petrol Specification**

| Description | Value |
|---|---|
| Density @ 15$^0$C, kg/l | 0.733 |
| Research Octane Number (RON), g/l | 97.0 |
| Lead Content, kPa | 0.008 |
| Reid Vapour Pressure, %wt | 62 |
| Total Sulphur | Trace |
| Distillation<br>50% evaporated, $^0$C<br>90% evaporated, $^0$C | <br>105<br>152 |
| Colour | Yellow |

In the second stage of the development, the motorcycle conversion kit as well as the natural gas cylinder were brought to MODENAS and assembled at site for the exhaust emission and performance test. A complete set of chassis dynomometer and emission analyzer was used. A new motorcycle was provided by MODENAS for this test. In a final stage, a prototype of the 4-stroke natural gas motorcycle was fabricated in Univesiti Teknologi Malaysia. This prototype is able to run on roads similar to normal motorcycle and it is specially fabricated for the purpose of exhibiting its potential ability in the future. The vision of this project is to reduce the 50% of air pollution, which is contributed from the natural gas powered motorcycle.

## ECONOMICAL BENEFIT OF NATURAL GAS MOTORCYCLE

Currently, all alternative fuelled vehicles have a price premium over traditional fuelled vehicles (unless manufacturers have special promotional prices that they subsidised). The natural gas motorcycle has high potential economic value in the future. A study on the operation costs indicated that over a distance of 120km, the natural gas motorcycle required RM1.00 on fuel compared to RM4.00 for a motorcycle fuelled by petrol. This study has been based on the current petrol cost of RM1.10 per litre. Compressed natural gas costs RM0.565 per litre (energy equivalent). Apart from the above, the Malaysian Government has given incentives to NGV users such as 25% reduction over the tax on bi-fuel vehicles. This is likely to be applied on natural gas motorcycle in future as well.

The safety aspects of converting vehicles to run on CNG are the concern of the public. Vehicles that run on clean burning natural gas are as safe as vehicles operating on traditional fuels such as gasoline. The low density of methane coupled with a high auto-ignition temperature (540$^0$C compared with 227-500$^0$C for petrol and 257$^0$C for diesel fuel) and higher flammability limits gives the gas a high dispersal rate and makes the like hood of ignition in the event of a gas leakage is less than for petrol or diesel. Additionally, natural gas is neither toxic, carcinogenic nor caustic.

## SAFETY ASPECT OF NATURAL GAS MOTORCYCLE

There are two fundamental reasons for this excellent natural gas motorcycle safety record: the structural integrity of the natural gas motorcycle fuel system and the physical qualities of natural gas as a fuel. The fuel storage cylinders used are stronger than gasoline fuel tanks. Cylinders are tested before installation to a pressure of 3000 psi. The design of natural gas motorcycle cylinders are subjected to a number of federally required "severe abuse" tests, such as heat and pressure extremes, collision, fires and impact upon accident. While fuel storage cylinders are stronger than gasoline fuel tanks, the composite materials used to encase the tanks are fundamentally more susceptible to physical damage than metals under abusive conditions. Natural gas motorcycle fuel systems are "sealed" which prevents any spills or evaporative losses. Even if leakage is occurring in a natural gas motorcycle fuel system, the natural gas will dissipate into the atmosphere because it is lighter than air.

The natural gas motorcycle is targeted at Malaysia, as well as international market for people of all ages. Because of its environmental friendly behaviour, the natural gas motorcycle is the motorcycle that is most sought after the cities are badly affected by pollution. By taking its size into consideration, it is the motorcycle with good accessibility for all kind of conventional purposes.

## EMISSION AND PERFORMANCE OF NATURAL GAS MOTORCYCLE

The exhaust emission for both gasoline and natural gas was analysed at idle speed and average speed of 40 – 90 km/hr. This emission analysis is in accordance with the ISO3929 test procedure. The motorcycle was tested on a chassis dynamometer at various constant speeds of 0, 40 to 90 km/hr, respectively. The amounts of composition exhaust emission gases are summarised in Figure 3, 4 and 5. This test was conducted using Horiba MEXA 324J Infrared emission analyser.

## TEST RESULTS

### Carbon Monoxide (CO)

CO emission (Figure 3) at idle speed from natural gas motorcycle was at an average of 0.01 % vol. which is equivalent to 99.7% decrease compared to gasoline powered-motorcycle (3.998 % vol.). At constant speeds (Figure 4) of 40 to 90km/hr, the amount of CO from natural gas powered motorcycle was between 0.02-0.06% vol. due to complete combustion of natural gas compare with gasoline.

### Unburned Hydrocarbon (UHC)

The amount of UHC (Figure 5) emitted by natural gas motorcycle was 79.3% lower than gasoline motorcycle, which is equivalent to 48.875 vol. ppm at idle speed. Similar result was obtained for constant speed of 40-90km/hr where the natural gas motorcycle produces UHC at approximately 48 ppm.

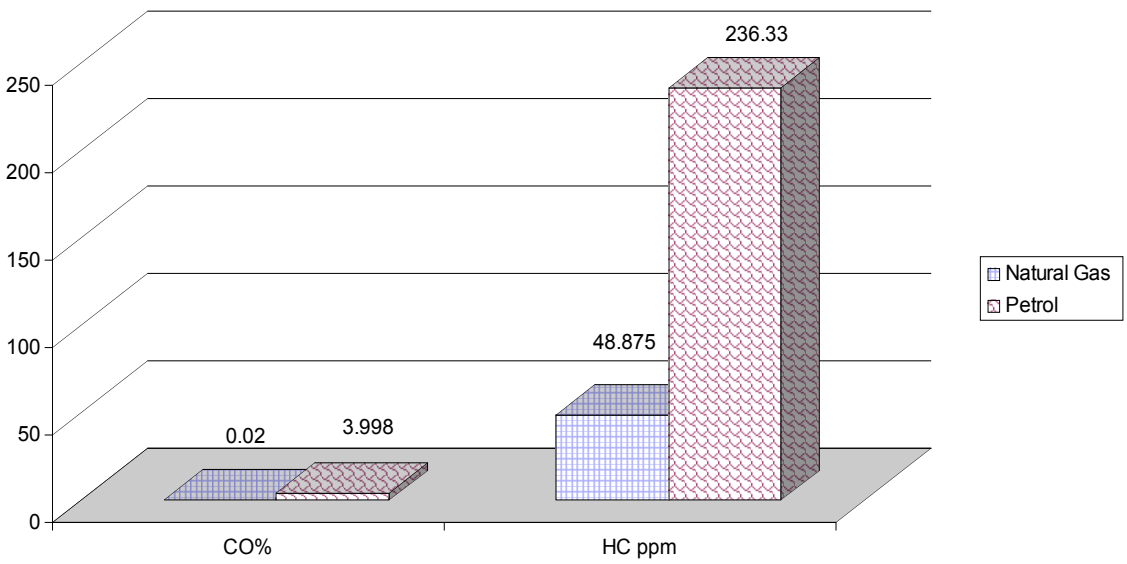


**Figure 3 : Idle speed Exhaust Emission**

## Performance Tests

Figure 6 show the maximum engine power as a function of engine speed for both fuels. The results are obtained at wide-open–throttle with manufacturer setting ignition timing. During the operation using natural gas, the power is seen reduced by approximately 15% at high engine speed. This power loss is due to the displacement of air by natural gas and low burning velocity of natural gas compared to gasoline. As a result, the natural gas powered motorcycle requires advance spark ignition timing compared to gasoline. At high engine speed, the engine power and torque are further decreased, due to the design of mixer that is not suitable for high gas flow rate.

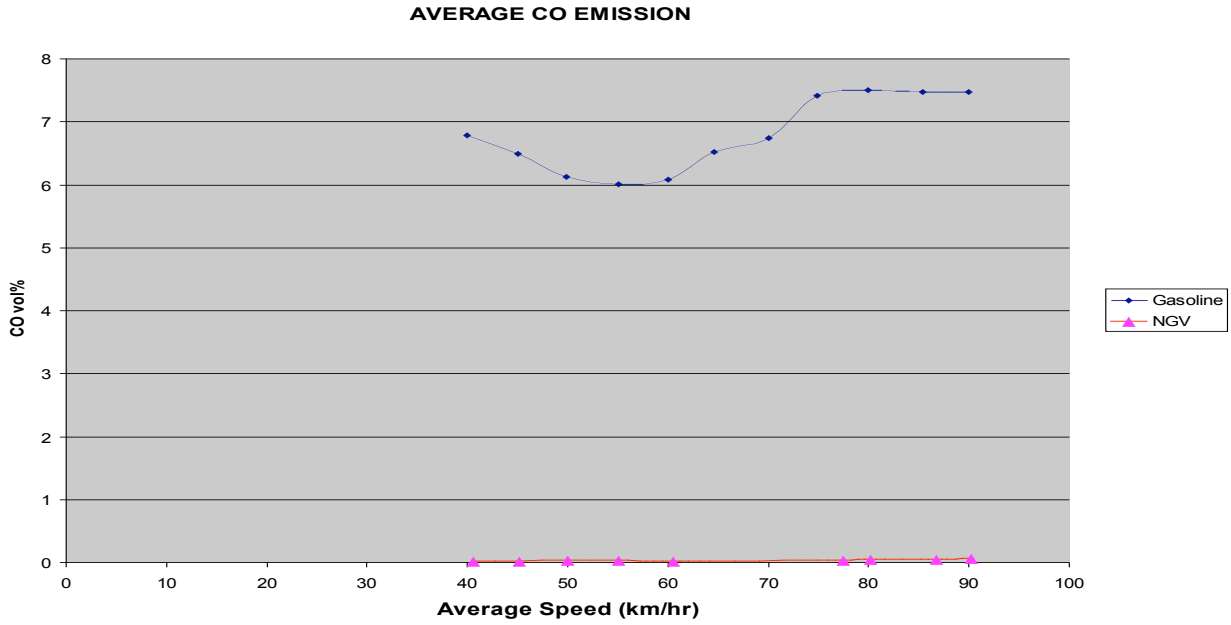


**Figure 4 : Constant Speed Carbon Monoxide Emission**

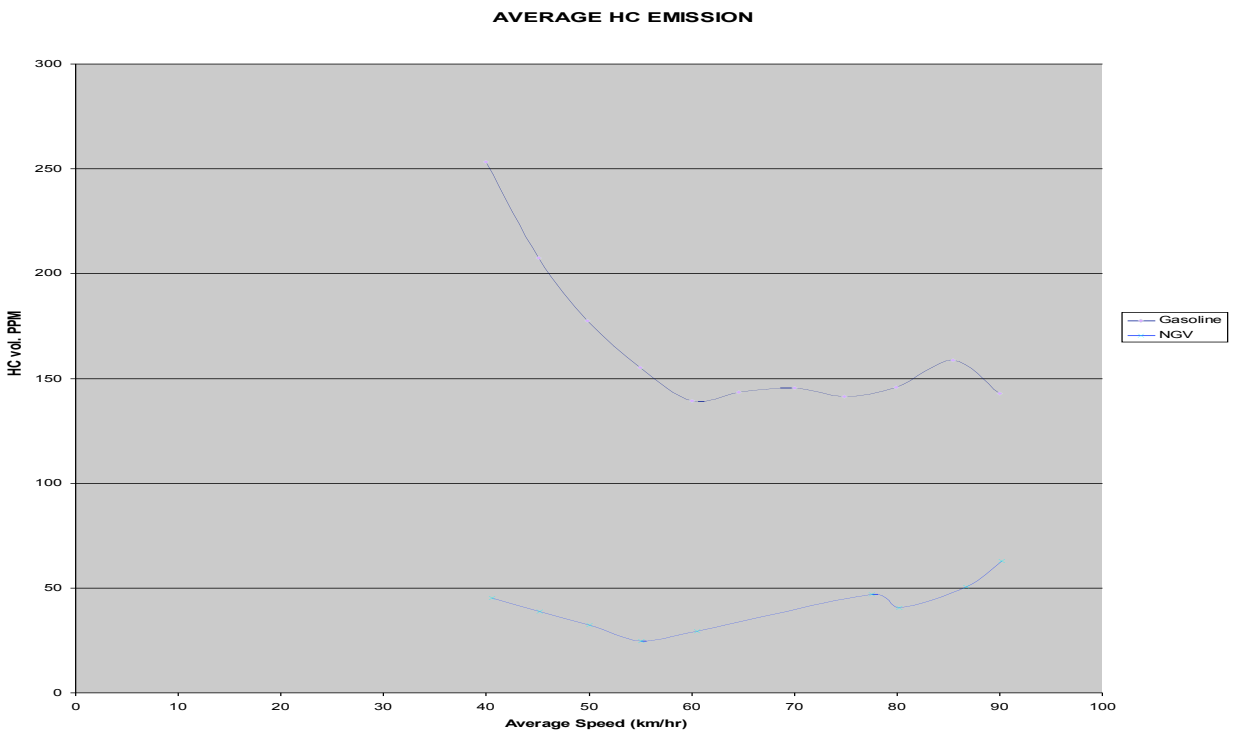


**Figure 5 : Constant Speed Unburned Hydrocarbon Emission**

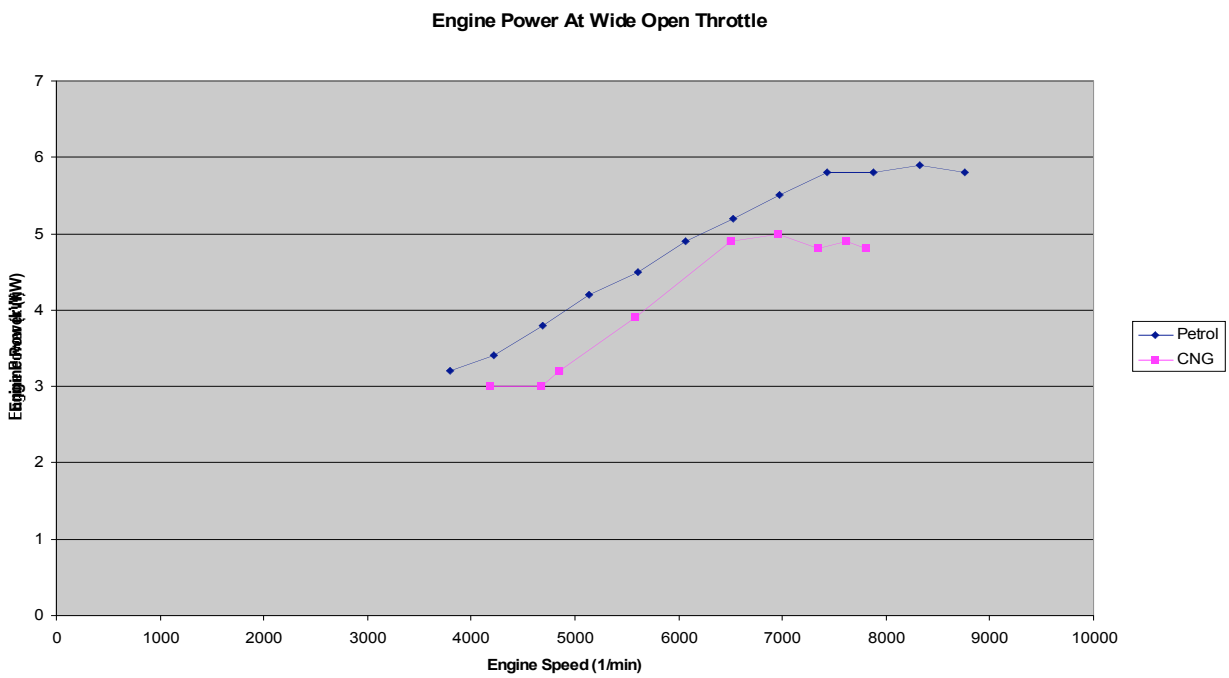


**Figure 6 : Engine Power Versus Engine Speed**

## CONCLUSION

Natural gas large reserve base lends itself to opportunities for exploration of the resources not only to generate foreign exchange earning through export of liquefied natural gas and piped gas but also fuel nations demand energy for industrialization and to spawn other ancillary and related industries, including the development of the natural gas vehicles especially for motorcycles. Since motorcycle is a second major source of pollutant in Malaysia and quite critical to environment and human health especially in city centre like Kuala Lumpur, the initiation of natural gas powered motorcycle is the best solution to decrease air pollution in our country. Natural gas powered motorcycle totally eliminates nitrogen oxides and give a significant decreases on CO and HC emission. Therefore, natural gas motorcycle is the key of the next millennium with clean city transportations. In addition, these results would be useful as a guide to the motorcycle industries using natural gas as the fuel and also to the nation to achieve Vision 2020, which could account for the Malaysia's technology.

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