DESIGN OF A COMPRESSED NATURAL GAS (CNG) MIXER FOR 1500CC ENGINE

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ABSTRACT

Natural gas vehicle (NGV) is a new discovery technology in Malaysia. Some advantages of the characteristic of natural gas compared to conventional fuel make it become the most important alternative fuel. The mixer is an important device in a compressed natural gas (CNG) kit to provide a proper air-fuel mixture for engine to run in the optimum condition. In this report, the literature of natural gas is presented and the characteristics of air and gas flow in the mixer is simulated using COSMOS software in order to have a better understanding of how mixture of air and fuel through the CNG mixer. A test on a 1500cc engine also been done to evaluate the designed mixer performance.

ABSTRAK

Teknologi Automotif menggunakan gas asli sebagai bahan api merupakan satu bidang yang baru dipelopori. Pelbagai kelebihan yang terdapat pada ciri-ciri gas asli berbanding dengan bahan api yang lain menjadikannya salah satu bahan api alternatif yang sangat penting pada masa kini. Mixer merupakan satu alat yang penting dalam sistem kenderaan yang menggunakan gas asli mampatan terutamanya untuk menyediakan campuran udara dengan gas yang sempurna kepada enjin supaya enjin dapat berfungsi dengan baik. Dalam laporan ini, kajian ilmiah mengenai gas asli telah dibentangkan dan sifat-sifat aliran udara dan gas asli dalam mixer disimulasi dalam perisian COSMOS untuk memahami dengan lebih mendalam lagi bagaimana udara dan gas mengalir melalui mixer. Satu kajian terhadap sebuah enjin 1500cc dilakukan untuk menguji prestasi mixer baru yang direkabentuk itu.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Qa	-	Engine flow rate
A	-	Cross section area
A/F	-	Air/Fuel
N	-	Engine speed
η_v	-	Volumetric efficiency
V	-	Engine displacement
ma	-	Air mass flow rate
mf	-	Fuel mass flow rate
P	-	Pressure
CO_2	-	Carbon Dioxide
T	-	Temperature
R	-	Gas constant
ρ	-	Density
V	-	Velocity
g	-	Gravity
rc	-	Compression ratio
rpm	-	Revolution per minute

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Natural gas vehicle (NGV) is a new discovery technology in Malaysia. Some advantages of the characteristic of natural gas compared to conventional fuel make it become a most important alternative fuel. The mixer is an important device in a compressed natural gas (CNG) kit to provide a proper air-fuel mixture for engine to run in the optimum condition. Compressed natural gas (CNG) also called as a natural gas vehicle (NGV) is an alternative fuel that is suitable for automotive use. It is actually the product of the underground decay of organic residuals (animal, plant, etc) that have changed their molecular structure over thousands of years. Then chemical process take place compressed over the organic residuals at high pressure (200bar, approximately 3000psi) and become one of the alternatives to replace the petrol as a fuel. Compressed natural gas contains 92.29 of methane and the rest are other gas such as buthane, propane and other trace gases. Therefore compressed natural gas formally known as methane. Actually there are many advantages of the compressed natural gas compared to the petrol. The advantages are the life of an engine actually increases economical, low emission, better drivability and other advantages. In this project, a proper design of the CNG mixer must be construct according to a proper calculation of the air flow.

1.1 Objectives

The performance of compressed natural gas engine in term of power output, brake torque, and volumetric efficiency is very sensitive to the air/fuel mixer design. A litter lack in the mixer design will cause a number of performance drop in the CNG engine. Therefore, a proper design of mixer is very importance in a CNG conversion system. The objective of this work is to design a most suitable CNG mixer for a 1500cc engine air requirement.

1.2 Scope

The scope of this work is:

1. Design a CNG fuel/air mixer, which suitable for a 1500cc four cylinder in-line engine with mechanical conversion system. More concern will be put on the CNG inlet of the mixer and the flow in the mixer.
2. Construct a designed mixer and run an analysis by using COSMOS Flow Works

1.3 Problem Statement

Although there is several of benefits of natural gas fuel, however, current natural gas engine are simply the conversion either the petrol or diesel that are far away from the optimum design. It causes a drop in engine power outputs and efficiency. Generally the conversion of gasoline engine to natural gas will cause a power loss of 10 to 30 percent. The air/fuel mixer restriction to the air flow causes a large part of the losses. About 10 to 20 percent of the 30 percent losses are associated to the obstruction of air flow by the mixer itself.

Although there is various types of mixer in the market percent time, but for every single engine the requirement to the mixer is differences. Therefore, for an

engine to achieve the optimum performance when running with CNG, a deeper study on the air/fuel mixer device should be carried out

1.4 Previous Study

According to the previous study on design the CNG mixer, still the result not achieve the optimum performance on the engine which means the mixing of air and fuel still cannot give the engine a better performance while the engine running on CNG as a fuel

1.5 Expected Outcome

In this final year project, the expected outcome is to design a CNG mixer with proper parameters to achieve optimum performance and better air/fuel ratio

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, discussed about the literature study related to the project. Including the definition and details about the compressed natural gas such as the background of the compressed natural gas, the advantages by using the CNG in vehicle, the contents of the compressed natural gas and how that compressed natural gas exist and the process, the conversion system of the CNG vehicle and also the component for the conversion system from petrol to CNG. In this chapter also discussed about the application in the CNG mixer how it works and how the air flow through the mixer.

2.2 Alternative Fuel

Convention fuels have remained almost unchallenged since the motor vehicle was invented. However, their source is finite. Recent estimates of the remaining petroleum resources in the world both in known field and those to be discovered should last between 40 and 70 years at current rates of usage. Our own country, Malaysia has about 4.3 billion barrels of crude oil that will last for only 19 years. At the same time, there will likely increase the number of automobiles and other internal combustion (IC) engines. Although fuel economy of engine is greatly improved from the past and will probably continue to be improved, numbers alone dictate that there

will be a great demand for fuel in the future years. Gasoline will become scarce and costly. So, it is important for us to be prepared for a future with alternative fuel.

Another reason motivating the development of the alternative fuel for IC engine is concern over the emission problem of gasoline engine. Compare with other air-polluting system, the large number of automobiles is a major contributor to the air quality problem of the world. Vast improvements have been made in reducing emissions given off by an automobile engine. Additional improvement such as using alternative fuel is needed due to the increasing number of automobiles. Emissions from electricity, natural gas can be as much as 90 percent lower in toxins than emissions from vehicle fueled with gasoline.

However, very few alternative fuels have been used commercially. The main problem is most alternative fuels system is very costly at present. The cost of manufacturing, distribution, and marketing all would be less. Another problem with alternative fuels is the lack of distribution points (fueling station) where the fuel is available to the public. The public will be reluctant to purchase an automobile unless there is a large-scale network for fueling station. On the other hand, it is difficult to justify building the network for these service stations until there are enough vehicles to make them profitable. Anyway some cities in developed countries are starting to make available a few distribution points for these fuels, like propane, natural gas and methanol. At the same time, some third world countries have been using manufactured alcohol fuel as their main vehicle fuel due to the high cost of petroleum product.

2.3 Natural Gas

Natural gas is one of the most abundant fuels in nature. Although we do not have an absolute estimate about planetary reserves, we can safely assume that natural gas is more abundant than oil and as an automotive fuel, is second only to hydrogen. Natural gas is the product of the underground decay of organic residuals (animal, plant, etc) that have changed their molecular structure over thousands of years. This

is the most common explanation for the formation of natural gas, also called "Organic Theory ". During countless millions of years, dead plants and animal sunk at the bottom of lakes and oceans. These remains were covered by mud, sand and other debris. The accumulation of such materials exerted high pressures on the buried materials with the passing of the millennia. Such pressures in turn created high temperatures. Chemical action took place and converted these remains into natural gas and crude oil.

In its pure state, natural gas is odorless, colorless, and tasteless. Natural gas is a mixture of components, consisting mainly of methane (about 92 percent). The other 8 percent is made up of various gases along with small amounts of water vapor. These other gases include butane, propane, ethane and other trace gases. So, natural gas is always referred as methane. Table 1.1 shows typical composition of natural gas.

Table 2.1: Typical composition of natural gas

Component	**Volume Percent**	**Mass Percent**
Methane	92.29	84.37
Ethane	3.60	6.23
Butanes	0.29	0.99
Pentanes	0.13	0.53
Propane	0.08	2.06
Hexanes	0.08	0.39
Nitrogen	1.80	2.89
CO_2	1.00	2.52
Water	0.01	0.01
Total	100.00	100.00

2.4 Compressed Natural Gas as Fuel

Natural gas has been used as a stationary IC engine for many years. Recently, its potential use as vehicle fuel received much attention. Among the alternative fuel choices, natural gas seems to have a number of advantages. Substantial supplies of natural gas exist worldwide with much available in North America. At present, Malaysia has 2.3 trillion cubic meters (m^3) of natural gas reserves, which can last 80 years. Natural gas can be adopted in a wide range of automobiles (from light-duty passenger vehicles to heavy- duty utility vehicle). The use of natural gas of transportation fuel will also lessen the dependence on petroleum products.

Because of its clean burning nature and the fact that it is not made from petroleum as gasoline and diesel are, many automakers around the world are developing vehicles to run on natural gas. Cars, vans, buses and small trucks generally use natural gas that has been compressed, called compressed natural gas (CNG) and stored in high pressure cylinders. A compressed natural gas vehicle stores gaseous fuel at pressure of 165.5bar (2400psi) to 248.3bar (3600psi). Even at a pressure of 248bar (3600psi), a unit volume of CNG has less than one-fourth of the energy content of gasoline, which means a much greater storage requirement for the vehicle.

Table 2.2: Energy content of alternative fuels relative to petrol and diesel (Maxwell, 1995)

Fuel	Density (kg/m3)	Energy Content (MJ/m3)	Energy Relative to equivalent mass of Petrol	Energy Relative to equivalent mass of Diesel
Petrol	621.8	4257	100%	91%
Diesel	622.2	4694	110%	100%
LPG	422.1	3113	115%	109%
Methanol	658.5	2100	49%	45%
Ethanol	652.5	2813	66%	60%
NG	351.2	2814	120%	113%

Table 2.3: Proven natural gas reserves, 1991, (Poulton, 1994)

Area	Trillion Cubic Meters	Billion Tones Oil Equivalent	Share of Total (%)
North America	7.5	6.7	6.1
Latin America	6.8	6.1	5.4
Western Europe	5.1	4.6	4.1
CIS/E Europe	50	45	40.4
Middle East	37.4	33.7	30.1
Africa	8.8	7.9	7.1
Asia/Australasia	8.4	7.6	6.8
Total	124.0	111.6	100.0

2.5 Advantages of Using CNG on the Engine

1. Economy:

   i) CNG is the most economical fuel and saves more than 55 % of your fuel expenditure over petrol.
   ii) It eliminates frequent vehicle maintenance.
   iii) Due to the absence of any lead content in CNG, the lead fouling of plugs is eliminated and plug life is greatly extended

Table 2.4: Different price between Petrol and CNG

	Petrol	CNG	Savings
Cost per liter.	RM 1.92	RM 0.81	-RM 1.11
Cost of 8 liters.	RM 15.36	RM 6.48	RM 8.88
Monthly Consumption.	RM 59.52	RM 25.1	RM 34.42
Yearly Consumption.	RM 700.8	RM 295.53	RM 405.27

2. Drivability:

CNG provide easy starting and smooth acceleration. While running on CNG, there is a power loss of approximately 5-15%, which can be minimized by using kits with a variable mixer and proper tuning (advancing the spark timing).

3 Environmental Friendly:

Environmental benefits provide an important argument for promoting natural gas in mobile applications. Since methane is the largest component of natural gas, we generally use the properties of methane when comparing the properties of natural gas to other fuels. Methane is a simple hydrocarbon, a

substance consisting of carbon and hydrogen. There are many of these compounds, and each has its own number of carbon and hydrogen atoms joined together to form a particular hydrocarbon gas or fuel gas. Its simple, one carbon, molecular structure (CH_4) makes possible its nearly complete combustion. Its much simple and smaller molecules compare with gasoline (C_7H_{16})

2.6 Engine Conversion

Both gasoline and diesel engines can be easily converted to gas operation. Conversion from a gasoline engine to gas is very simple and straight forward. It is only require a gas fueling system. Very litter or no modifications are needed to the base engine.

For converting a diesel engine to gas, a spark system has to be use to replace the diesel fuel injection system since natural gas is not the type of auto-ignition fuel. Natural gas needs a mixture temperature of approximately 1000^0C to ensure the auto-ignition.

Natural gas conversion systems for vehicle consist basically of two types, mechanical (carbureted) and electronic (fuel injected). Mechanical systems have been used for many years and operate on the same principles as gasoline carburetor fuel metering system. The natural gas is mixed with the intake air in a fuel/air mixer. Electronic system utilizes injectors or flow control valve to meter the fuel into the intake air. In this work, the study will be done on the mechanical conversion system of a 1.5L four cylinders spark ignition engine.

2.7 CNG Conversion System

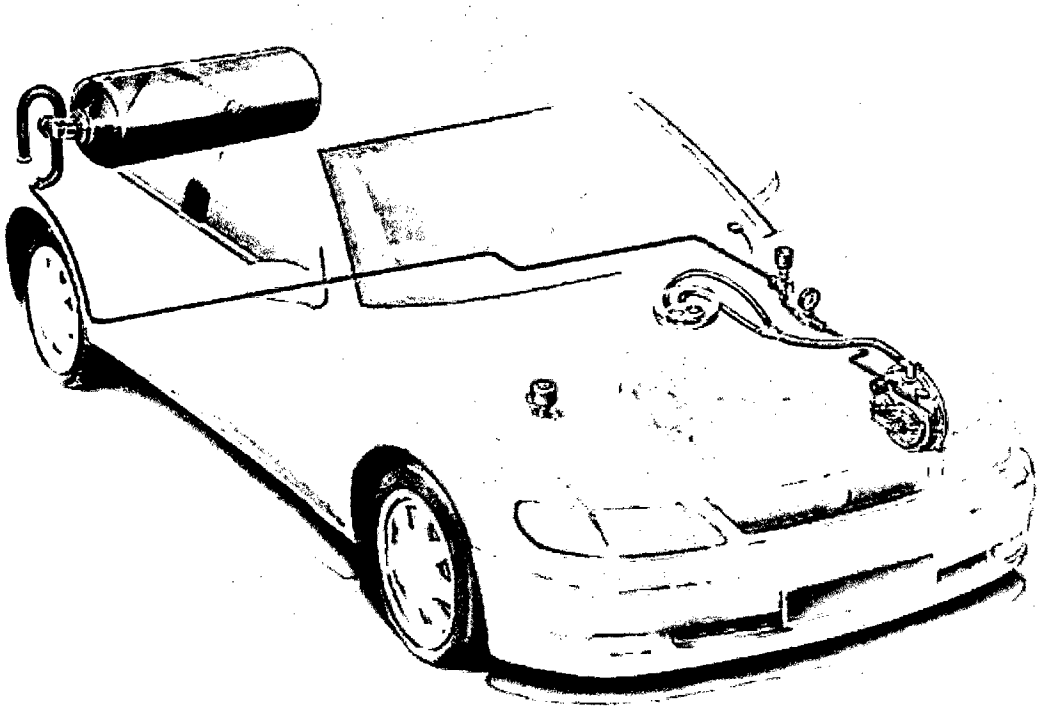


Figure 2.1: CNG conversion systems

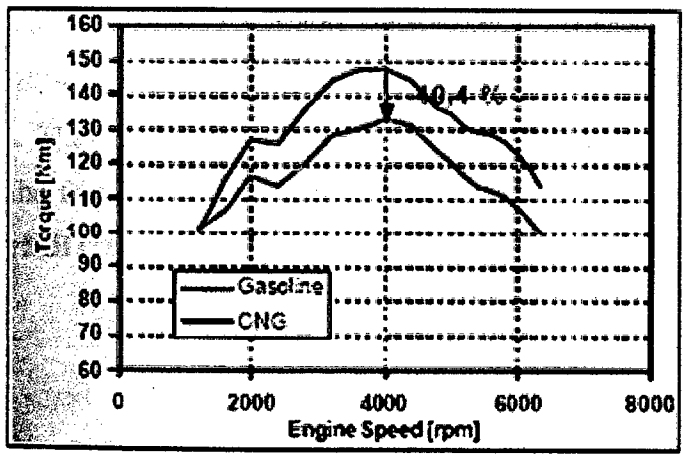


Figure 2.2: Torque of 1587cc Peugeot TU5JP4 with CNG conversion

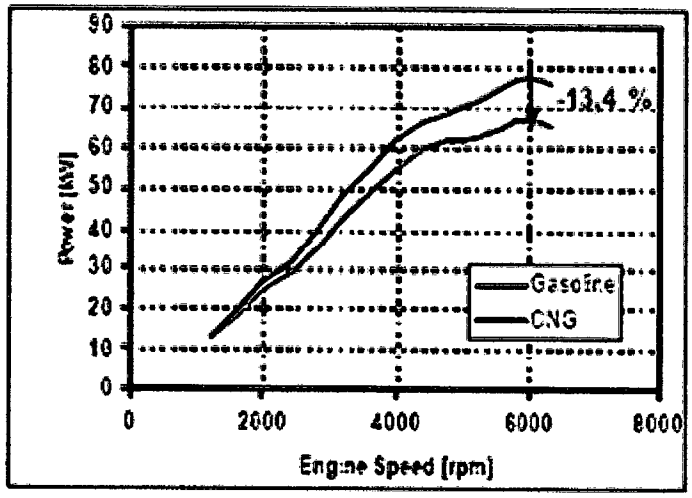


Figure 2.3: Power output of 1587cc Peugeot TU5JP4 with CNG conversion

Engine Performance

Power Output- Figure 2.3 shows the power characteristics of the test engine. The use of CNG led to 13.4% reduction in output and 10.4% torque reduction at WOT .For a petrol engine, power output tends to decrease around the stoichiometric A/F ratio because of thermal dissociation. To cope with the problem, thermal dissociation is avoided by setting the richer A/F ration. There was less thermal dissociation for CNG because the combustion temperature is low at around the stoichiometric A/F ratio. The torque difference between CNG and petrol engines is not conspicuous at low engine speed. They were almost the same up to 1500 rpm. This characteristic may result from the fact that CNG has a very high octane value, allowing ignition timing to be set at MBT(Minimum spark advance for best torque) at all engine speed.

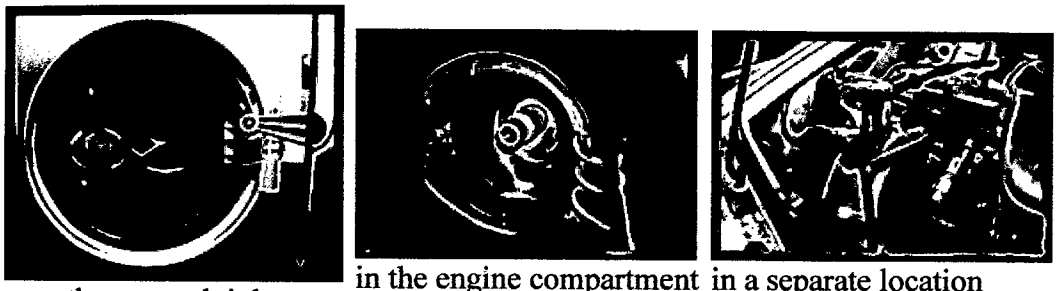
2.7.1 The Basic Component of a CNG Vehicle

1. Filler valve

The valve is used to fill the vehicle's pressure tank with natural gas at CNG fuel stations. The filler valve can be located in the engine compartment (the usual solution for converted automobiles), near the gas tank inlet, or separately in a different place.

There are two filling methods - the "Italian" system (used chiefly in Italy) and the NGV 1 system (used in other European countries).

NGV 1 inlet:



near the gas tank inlet | in the engine compartment | in a separate location

Figure 2.4: Filler valve at CNG vehicle

2.Pressure tank + multi-valve

Most tanks for pressurized natural gas have a volume of 70-100 liters and are fitted with a multi-valve for safe and reliable operation. The multi-valve functions as an operating device, which closes the pressure tank when the ignition is turned off and controls the amount of gas flowing from the vessel, and as a safety mechanism, which automatically shuts off gas flow if the piping system is damaged (pressure falls) and releases gas from the vessel if the pressure exceeds a certain value or if a heat sensor detects a fire.

Pressure tanks are usually made of steel, but an increasing number of lightweight tanks made from aluminum or composite materials, as strong as steel but