# A STUDY ON THE OPTIMUM NATURAL GAS STORAGE TANK DESIGN USING THE GAS ADSORBENT APPLICATION

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‘I/We* admit that have read this dissertation and in my/our* opinion this dissertation is satisfactory in the aspect of scope and quality for the bestowal of
Bachelor of Mechanical Engineering (Automotive)’

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This report is submitted to the Faculty of Mechanical Engineering
in partial fullfilment of the partial requirement for awarding the
Degree of Mechanical Engineering
(Automotive)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

MAY 2009

"I admit that this report is my own work except the summary and some statement which is each of them, I already state the source of it"

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## ACKNOWLEDGEMENT

First of all, I would like to express all my praise to Allah the Almighty because without His blessings I will not be able to complete my Projek Sarjana Muda 1 and II (PSM), which is part of the course requirement that I have to go through in Universiti Teknikal Malaysia Melaka (UTeM).

Especially, my most gratitude goes to those individuals who have contributed immeasurable amount of guidance, advice and assistance along the project period; the first person that really helps in my research is my dedicated supervisor, En. Razali Mohd Tihth, who has supportively guiding and teaching a lot of valuable knowledge, also for the opportunities he has given me in exposing myself to research and development environment.

And also the supportive BMCA member, I would like to thank all of them for lending their hands and giving continuous support during my project period in order to achieve the objective of study. With the full cooperation from the people above, I have successfully achieved the objectives of PSM I and II.

## ABSTRACT

A natural gas is one of the alternative fuels for vehicles around the world and most of the vehicle nowadays used Compressed Natural Gas (CNG). Among the problem of using the CNG equipment is on the storage tank size and its high operating pressure. The storage tank is bulk, thick and heavy because it has to sustain the higher compression of methane ($CH_4$) gas. In this research, the application of carbon adsorbent is used in ANG concept storage tank. This study is focusing on the amount storage capacity of Adsorptive Natural Gas (ANG) compared to the available existing 12 litre CNG tank in the market. Methane adsorptive storage will be done using the designed adsorbent tank concept. This carbon adsorbent will be used in the process of design and studies the new storage tank in the future. The expected result in this research is being able to set up an experiment procedure for testing the adsorbent ability storage using coconut palm shell carbon. This carbon adsorbent will be applied in the ANG storage tank concept. If this research success, the problem such as large size and high pressure of natural gas storage can be solve.

# ABSTRAK

Gas asli ialah salah satu alternatif minyak untuk kenderaan di seluruh dunia dan kebanyakan kenderaan sekarang menggunakan storan gas asli termampat (CNG). Antara masalah daripada penggunaan storan gas asli termampat (CNG) ialah pada saiz storan tangki dan operasi tekanan yang tinggi. Storan tangki gas asli termampat besar, tebal dan berat kerana terpaksa menampung tekanan mampatan gas metana yang tinggi. Dalam penyelidikan ini, aplikasi penjerap akan digunakan di dalam gas asli terjerap (ANG) storan konsep tangki. Kajian ini bertumpu pada jumlah kapasiti storan penjerapan gas asli (ANG) tangki berbanding dengan 12 liter storan tangki termampat (CNG) yang sedia ada di pasaran. Storan penjerapan metana akan dilakukan dalam rekabentuk konsep penjerapan tangki. Karbon penjerap ini akan digunakan dalam mereka bentuk dan kajian tentang storan tangki baru pada masa akan datang. Jangkaan keputusan dalam penyelidikan ini ialah dapat menyediakan satu kaedah eksperiman untuk menguji kebolehupayaan storan penjerap menggunakan karbon tempurung kelapa sawit. Karbon penjerap ini akan digunakan dalam gas asli terjerap (ANG) storan konsep tangki. Jika penyelidikan ini berjaya, masalah seperti saiz storan tangki yang besar dan tekanan tinggi daripada storan gas asli dapat diselesaikan.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ANG | = | Adsorbed Natural Gas |
| CNG | = | Compressed Natural Gas |
| CO | = | Carbon Monoxide |
| LNG | = | Liquefied Natural Gas |
| MPa | = | Megapascal |
| NGV | = | Natural Gas Vehicle |
| NMHC | = | Non-methane Hydrocarbon |
| $NO_x$ | = | Oxide of Nitrogen |
| O | = | Oxygen |
| ppm | = | Part per million |
| psi | = | Pound per square inch (Ibf/in2) |
| STP | = | Standard Temperature and Pressure |
| upm | = | Unit per million |
| V/V | = | Volume of Adsorbed Gas per Volume of Solid Adsorbent |
| $V_m/V_s$ | = | Volume of Stored Methane per Volume of Storage Container |

| | | |
|---|---|---|
| Ni | = | Nikel |
| Cr | = | Chromium |
| C | = | Carbon |

# LIST OF APPENDIX

# CHAPTER 1

## 1.0 INTRODUCTION

### 1.1 General Background

Natural gas vehicles or commonly known as NGV is one of the cleaner fuel used through out the worlds as the alternative to gasoline for most of the vehicles. Natural gas comes from the decay of ancient organism buried on the ocean floor. The tiny bacteria continuously brake down the remains of sea animals and plants. Over time, they were covered by layers of sedimentary rock. After millions of years the remains were buried deeper and deeper which turned them into the oil and gas because of the enormous heat and pressure under the ocean (Secondary Energy Info Book, 2007). Today, human drill down through the sedimentary rock layers to reach the oil and gas deposits as shown in Figure 1 below.

Natural gas consists of about 95% methane, a gas that is unable to be liquefied at ambient temperature by pressurization because of its critical temperature which is the $T_c$ is - 82.6 $^{o}$C. Since it is a gaseous fuel, its volumetric energy content is low compared with those of liquid fuels (Mota, 1999). In fact, natural gas outscores petroleum-based fuels in every aspect except on board storage (Talu, 1992). Currently, natural gas is compressed at pressures up to 25 MPa (3600 psi) in order to be stored compactly on-board and dispensed quickly.

However, this storage method requires expensive and extensive high-pressure compression technology (Jasionowski *et al.*, 1989).

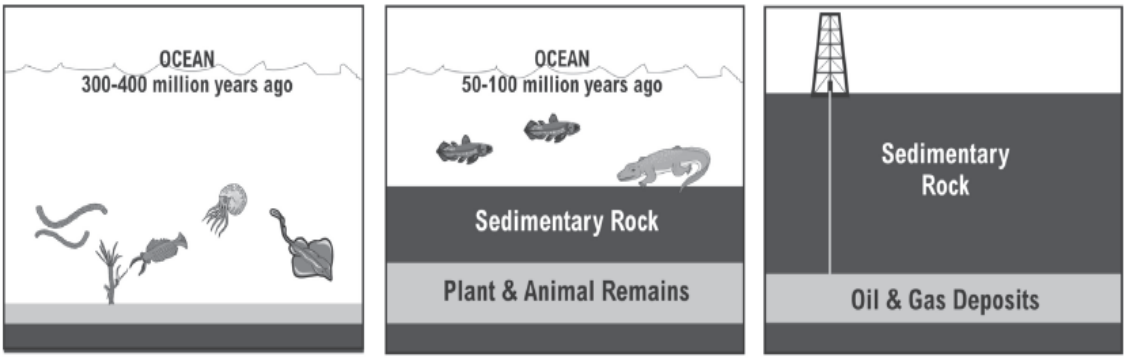


Figure 1: Oil and Natural Gas Formation

The primary component of natural gas is methane ($CH_4$), the shortest and hydrocarbon molecules (Physical and Chemical Fundamentals McGraw Hill, 1975). The hydrocarbon in natural gas called saturated hydrocarbons because they contain hydrogen and carbon. This gas methane has to be compressed into the appropriate size storage tank cylinder with very high pressure due to the characteristic of methane molecules which are difficult to pack closely together, so natural gas must be subjected to high pressures to store enough of it to fuel a vehicle over a long distance.

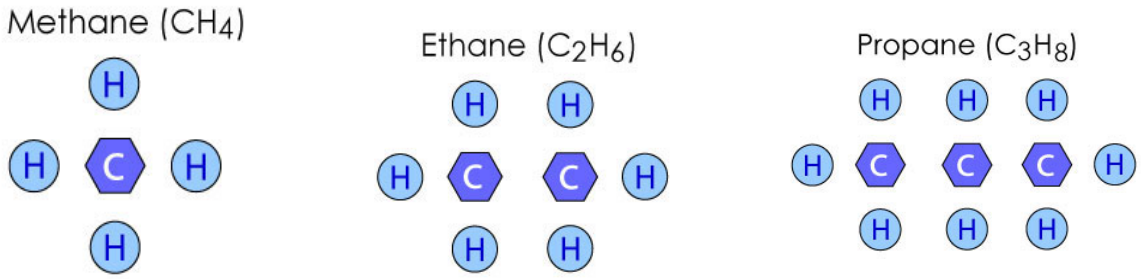


Figure 2: Diagram of Simplest Saturated Hydrocarbon

## 1.2 Objectives

This research is focusing on the studies the optimum natural gas storage tank design storage using coconut palm shell carbon as the gas adsorbent application and set up one procedure experiment to testing this adsorbent material in the ANG tank concept. All the measurement and control devices which is need to be used in this experiment will be identified and stated. The other objective of this study is to discuss the concept of new ANG storage tank.

## 1.3 Problem Statement

Nowadays NGV is widely used all around the word as the alternative fuel for vehicles. Lot of vehicle users today either passengers or commercials have installed the NGV kits on their vehicles because the vehicles users cannot follow up the increasing price for fuel in global state. But the side effect that has to be accepted by NGV users is they have to give most of their boot cars space to install the NGV storage tank since this storage tank designed in large size, thick walled and cylinder shape in order to withstand the high pressure from the methane molecules of NGV.

Currently, natural gas is most practical when fueling large vehicles such as buses and trucks because it must be stored in large tanks that would take up all the storage space in smaller car. Due to this problem many researchers has run some research and experimental process to find the other ways to reduce the size of storage tank. One of the efficient methods is using the gas absorbent which generally known as Adsorbed Natural Gas (ANG).

## 1.4 Scopes

The scopes for this research are:

- To studies the optimum preparation process of carbon adsorbent material from waste material such as palm shell by applying the characteristic of natural gas adsorb and desorbs process to the carbon adsorbent material.

- To identify the related gas adsorption apparatus, measurement and control devices needed to be used in this experiment.

- To come out with the concept design of gas storage tank that fitted with the carbon adsorbent material by considering those characteristic.

- To set up one experiment procedure in order to testing the capability storage of carbon adsorbent material in the concept ANG tank.

- To discuss the ANG storage tank design material selection aspects.

## 1.5 Benefit of Study

Better understanding about the flow of NGV system, the characteristic, properties of natural gas and also the types of NGV. Most people did not realize that there are three types of NGV which are Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Adsorbed Natural Gas (ANG). This research will be focusing on the ANG but there are also some information about the CNG and LNG.

ANG is a new technology available to answer some difficulties of CNG storage for fleet application. In ANG storage, natural gas is adsorbed by a suitable high porosity adsorbent material packed inside the storage vessel. It takes place at a lower pressure, which is around 500 psi (3.5 MPa). When natural gas is charged into ANG tank, the energy density stored will be greater than of the CNG tank at the same pressure, increasing the amount of natural gas that can be stored. Subsequently, this will allow more gas to be stored at lower pressure.

By doing this research studies, hopefully at the end it will help the current problem that have to be faced by NGV user will be solved. The fuel vehicles user can take the alternative NGV as replacement of the fuel. These studies provide some info about the carbon adsorbent characteristic and gas adsorb-desorbs process which can be used for the further research. May be for the future the researcher can use the others waste material other than oil palm shell which suit with carbon characteristic to be used in the NGV storage tank.

# CHAPTER 2

## 2.0 LITERATURE REVIEW

### 2.1 Theory

Natural gas is a gaseous mixture of light hydrocarbons which is found underground in sedimentary rock formations, often in the same location as crude oil. It is colorless, odorless fuel that burns cleaner than many other fossil fuels such as coal, gasoline, and diesel. Natural gas consists of mainly methane (85-95%) with a minor amount of ethane, and higher-order hydrocarbon compounds. Natural gas also contains a scant amount of unburned component such as carbon dioxide, nitrogen and sulfur. However, the percentage of natural gas composition is different from one reservoir to another (Parent, 1986). Natural gas composition from Malaysian reservoir is as presented in Table 1. Once the gas has compressed into the storage tank it's called Compressed Natural Gas (CNG). Under natural gas vehicle (NGV) actually have three type of NGV system which are Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Adsorbed Natural Gas (ANG).

| Natural Gas Component | Volume Percentage | |
|---|---|---|
| | Before 1995 | After 1995 |
| Methane ($CH_4$) | 84.75 | 92.73 |
| Ethane ($C_2H_6$) | 10.41 | 4.07 |
| Propane ($C_3H_8$) | 0.98 | 0.77 |
| i-butane ($C_4H_{10}$) | 0.07 | 0.08 |
| n-butane ($C_5H_{10}$) | 0.04 | 0.06 |
| Other hydrocarbons ($C_{5+}$) | 0.00 | 0.01 |
| Nitrogen ($N_2$) | 0.39 | 3.36 |
| Carbon dioxide ($CO_2$) | 3.36 | 1.83 |
| Total | 1.83 | 100.00 |
| Gross Calorific Value, CV (Kcal/$Sm^3$) | 9.583 | 9.253 |
| Specific Gravity | 0.65 | 0.61 |

Table 1: Malaysian Natural Gas Composition (Gas Malaysia Sdn Bhd, 1995)

Since natural gas principal component is methane with 85 - 95% composition, therefore, the characteristics of natural gas are similar to methane. Methane is a colorless and odorless gas with a wide distribution in nature. At room temperature, methane is lighter than air. It melts at –183 °C and boils at –164 °C. Hence, at ambient temperature, methane cannot be liquefied by pressurization (Smith, 1990). This is because the critical temperature of methane which is –82.6 °C is lower than ambient temperature (27 °C). It can be liquefied only by cooling method and natural gas in this form is called Liquefied Natural Gas (LNG). Methane is not very soluble in water. It is combustible, and mixtures of about 5 to 15 percent in air are explosive. Methane is not toxic when inhaled, but it can produce suffocation by reducing the concentration of oxygen inhaled (Shakhashiri, 2000).

A trace amount of smelly organic sulphur compounds is added to give commercial natural gas a detectable odour. This is done to make gas leaks readily