THEORETICAL STUDY ON BIOGAS COMBUSTION

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This project report entitled "**THEORETICAL STUDY ON BIOGAS COMBUSTION**" was prepared by **Ismail b. Khalid** as a partial fulfillment of the requirement for the degree of Bachelor of Engineering with Honours (Mechanical and Manufacturing System) is hereby read and approved by:

_____ _____

Nazeri b. Abdul Rahman Date:

(Supervisor)

Dedicated to

Bapak & Mak

Almarhum Haji Khalid bin Kaderi and Hajjah Endon Haji Bolok

and family

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ABSTRACT

The main objective of this project is to analyse the biogas combustion and also to determine the brake thermal efficiency and power output operating on stoichiometric condition, weak mixture and rich mixture. It is also to analyse the effect of hydrogen addition in the stoichiometric combustion. Another objective is determining the composition of products for stoichiometric, weak mixture and rich mixture. The data gained based on chemical equations are use to plot the desired graph. The result of the analysis indicated that the brake thermal efficiency and power output increase as the methane percentage increase. Results also show that hydrogen addition significantly increases the power output.

ABSTRAK

Projek ini adalah berkenaan tentang kajian terhadap proses pembakaran biogas dan mengenalpasti kecekapan brek termal dan kuasa yang diperolehi ketika beroperasi dalam keadaan pembakaran lengkap, *(stoichiometric)*, *weak mixture* dan *rich mixture*. Projek ini juga mengkaji kesan penambahan hidrogen ke atas pembakaran lengkap (*stoichiometric*) dan mengenalpasti komposisi bahan keluaran dalam keadaan pembakaran lengkap, *(stoichiometric)*, *weak mixture* dan *rich mixture*. Data yang diperolehi berdasarkan persamaan kimia di plotkan di dalam graf dan dinilai. Keputusan yang diperolehi menunjukkan kecekapan brek termal dan kuasa yang dikeluarkan bertambah apabila kandungan peratus *metana* bertambah. Keputusan juga menunjukkan penambahan hidrogen meningkatkan kuasa keluaran.

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NOTATIONS

A	Air ratio
BDC	Bottom dead centre
Bp	Brake power
C	Carbon
C_2H_2	Acetylene
C_2H_4	Ethylene
C_2H_5OH	Methylated spirits
C_2H_6	Ethane
C_4H_{10}	Propane
C_5H_{12}	Pentane
CH_3OH	Methanol
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
D	Diameter of cylinder
F	Fuel
H_2	Hydrogen
H_2O	Water
ip	Indicated horsepower
L	Length of cylinder
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
m	Mass

m_{air}	Mass of air
m_{CH4}	Mass of methane
m_{CO2}	Mass of carbon dioxide
m_f	Mass of fuel
N	Speed Revolution
N_2	Nitrogen
NO	Nitric oxide
NO_2	Nitrogen oxide
O_2	Oxygen
p	Pressure
P	Power output
Q_v	Lower calorific value of fuel
r	Compression ratio
R	Radius
SFC	Specific fuel consumption
SO_2	Sulphur oxide
T	Torque
TDC	Top dead centre
V	Volume
VE	Volumetric efficiency
V_s	Swept volume
W	Load
W_b	Brake effective work
α	Methane fraction

β	Carbon dioxide fraction
ε	Mole fraction
ϕ	Equivalence ratio
ρ	Density
ρ_{CH4}	Density methane
ρ_{air}	Density air
ρ_{CO2}	Density carbon dioxide
η_{bte}	Brake thermal efficiency
η_m	Mechanical efficiency
η_v	Volumetric efficiency
ω	Hydrogen fraction

Chapter 1

Introduction

1.0 Introduction

Combustion is the oldest technology of mankind; it has been used for more than one million years. At present, about 90% of our worldwide energy usage support (e.g. in traffic, electrical power generation and heating) are provided by combustion. [Warnatz, 1996]

Combustion research in the past was directed to fluid mechanic that included global heat release simply description with the help of thermodynamics, which assumed infinitely fast chemical reaction.

Most of the time, combustion burns the air-fuel mixture in the internal combustion engine through oxidation. The aim is, at least, for satisfying the emission regulation during steady state cruising operation by combining all the hydrogen and carbon atoms in the fuels with all the oxygen from air. The process occurs in short time, which, the flame in the gasoline engine should spread progressively throughout the combustion

chamber, without spontaneous ignition occurs ahead of it. [Warnatz,1986] The detail process of combustion process will be explained later.

1.1 Energy

Energy is important to human being in this planet. It is the most important things apart of food and shelter. Energy can not be created or destroys but it is converted or distributed from one form to another. Natural resources provide us most of the energy. Energy is found in many forms, such as wind, flowing water, which is converted into hydroelectric power and stored energy such as fossil fuel such as oil, coal and natural gas as well. [Hinrichs, 1992]. According to Hinrichs, more than 40% of the world energy comes from oil, 27% coal, 20% gas and the rest contributed from hydro and nuclear. After the invention of the internal combustion engine in 1870s, oil consumption is increasing. Eventually, coal was replaced by oil in industries and power utilities. Today oil accounts for 45% of our fuel consumption. [Macdonald, 1986]

The increasing usage of oil in the world scenario has created the shortage of oil. At our present rate of usage this energy will last for only 70 years. [Macdonald, 1986]. If energy usage at the present rate, people would see major fuel shortage throughout the world. However, in the fear of fuel are running out, people starts to find alternative fuel. Some alternative fuels are "biomass energy". Energy derived from living matter such as field crops (corn, wheat), trees, and water plants; it is also derived from agricultural and forestry wastes (including crop residues and manure), and municipal solid wastes. Biomass can be converted into liquid and gaseous fuels. [Hinrichs,1992] The **Figure 1.1** and **Figure 1.2** show the total reserves of energy and the world energy usage respectively.

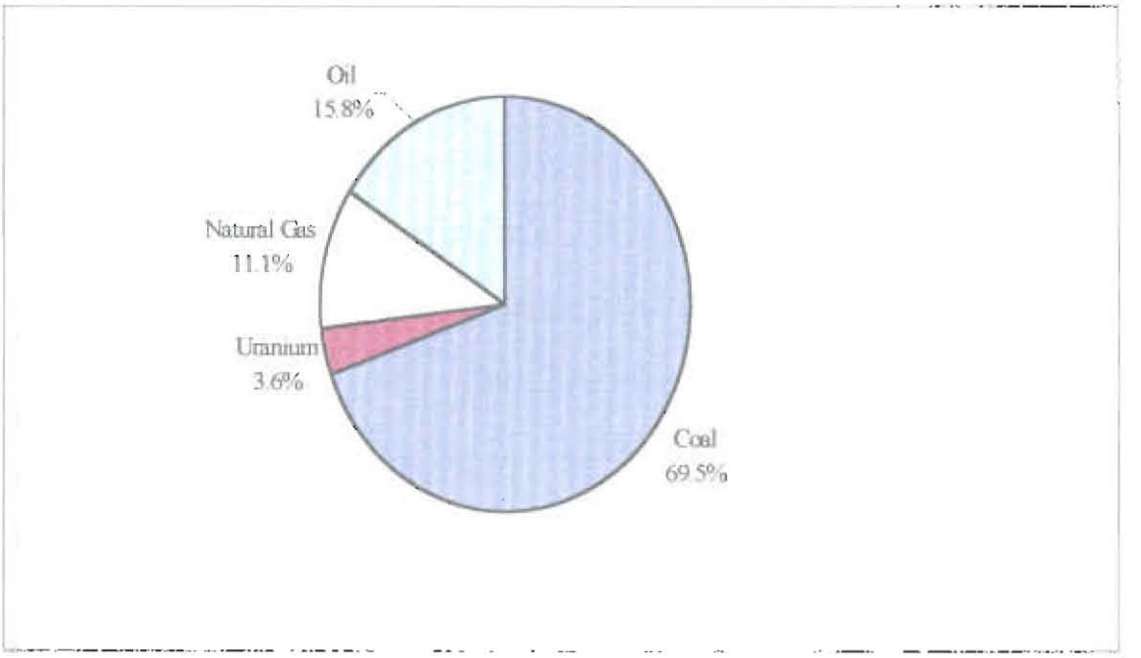

Figure 1.1 Total world reserves energy [Hinrich, 1996]

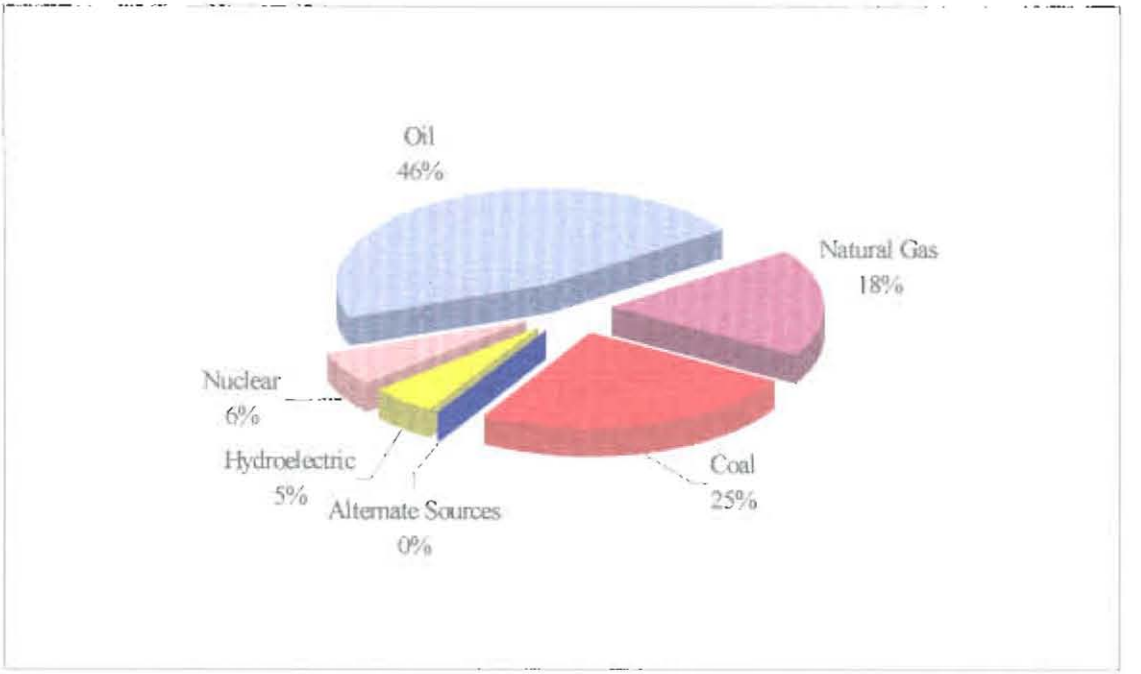

Figure 1.2. World source of energy [Hinrich,1996]

1.2 Fuel

Fuel as one source of energy can be defined as a sustained material for burning and produce power, heat and energy. So, in order for the combustion process occurs, it must have fuel. Fuel is divided into solid, liquid and gaseous. The two conventional liquid fuel normally use in automotive for instants are gasoline and diesel oil. Despite the facts that the world petrol is still widely used; engineers around the world and engine manufacturers are beginning to replace it with some other sources of fuel as an alternative. Hence an alternative engine and fuels are invented. Currently, very few vehicles for instants are run on fuels other than gasoline and diesel oil the principal alternative being liquefied petroleum gas (LPG). [Garrett,1991]

Both liquid and gaseous fuels used for combustion processes are hydrocarbon comprising mainly hydrogen (H_2) and carbon (C). Common fuels that are familiar from every day experience are gasoline and natural gas. All of these fuels contain hydrocarbon. Petroleum, which is a mixture of hydrocarbon and other mainly organic compound, found in natural underground reservoirs. The technical term is crude oils. It contains three main series of hydrocarbon: a group comprising alkanes and alkenes (sometimes called paraffins and olefins respectively), cyclo-alkanes (formerly called naphethenes) and the aromatics [Garrett,1991]

All of crude oil is compound of hydrogen and carbons. Each series also contains isomer. The process of crude oil distillation the produce gasoline, kerosene, diesel oil and lubricating oil.

According to Garrett, the prospect of our crude oil supplies is running out in the 21st century and alternative fuels are being investigated. The potential alternative fuels are liquid, liquefied gases and gaseous fuels. Among potential alternative fuel are

i. Synthetic hydrocarbons that normally come from coal.

ii. Alcohol, mostly methanol (CH_3OH), made from natural gas or coals or ethanol, ethyl alcohol or methylated spirits (C_2H_5OH) obtained from vegetable matter, the hydration of ethylene or acetylene or by catalytic synthesis from ethylene and water.

iii. Gasohol, which originated in Brazil, is a mixture of gasoline (70.9%) and ethanol (30.1%).

iv. Liquefied natural gas (LPG). This occurs naturally in the ground. It is mainly propane (C_4H_{10}) and possibly some ethane (C_2H_6) and even a little pentane (C_5H_{12}) and slightly heavier fractions in vapor form.

v. Liquefied natural gas (LNG). This comes principally from dry natural reservoirs. LNG is generally mainly methane (CH_4) but, in some circumstances, with very small proportion of ethane (C_2H_6) and propane (C_4H_{10}). Methane is better known as originating from decaying vegetable matter in, for example, sewage works, rubbish tips or marsh gas.

vi. Producer gas or water gas. This is a mixture of hydrogen (H_2), carbon monoxide (CO) and nitrogen (N_2).

[Garrett,1991]

1.3 Energy Content

Perhaps the most important property of any fuels is its energy density since this determine its commercial value obtainable per liter of fuel in the tank. Gasoline and diesel oil is extremely energy rich and moreover, easy to distribute and handle. Some relative energy content on both per volume and per weight basis as shown in **Table 1.1**.

TABLE1.1: RELATIVE ENERGY CONTENTS ON BOTH PER VOLUME AND PER WEIGHT BASIS [Garrett,1991]

	Fuels	(MJ/kg)	(MJ/m^3)
Liquid	Gasoline	43.5	
	DERV	42.5	
	Ethanol	26.8	
	Methanol	19.7	
Gaseous	Methane	50.0	3.22
	Butane	45.6	3.39
	Propane	46.3	3.35
	Hydrogen	120.0	2.97

1.4 Biogas

When organic matter decomposes in the absence of oxygen, a gas is evolved that is mostly methane and carbon dioxide, plus smaller amounts of other constituents. Sometimes, this decomposition occurs naturally around swamps. In other cases, a gas is produced when sewage is decomposed in wastewater treatment plants. This gas is

called "digester gas." Finally, solid waste deposited in landfills produces a gas when it decomposes. In this case, the gas is called "landfill gas." Collectively, these gas mixtures are known as **biogas.**

Biogas is a mixture of gasses composed chiefly of:

i methane (CH_4): 40-70 of volume percentage

ii carbon dioxide (CO_2): 30-60 of volume percentage

iii Other gasses: 1-5 of volume percentage including hydrogen (H_2): 0-1 of volume percentage & hydrogen sulfide (H_2S): 0-3 of volume percentage.

1.5 Combustion

The process takes place in a controlled manner in some form of combustion chamber after initiation of combustion by some means (e.g. in a petrol engine the combustion is started by an electric spark). The source of oxygen supply from air contains oxygen and nitrogen and traces of some other gases. All these gases accompany the oxygen into the combustion chamber [Eastop, 1996]. Proportionate masses of air and fuel entering the combustion chamber where the chemical reaction takes place and from which shows that

i. The reactants and the product of combustion.

ii. The relative quantities of the reactant product.

The equation must be consistent and it shows the number of molecules of each reactant and product.