Palestine Polytechnic University

College of Engineering

Investigating the Performance and Emission of the Gasoline and LPG Dual-Fuel Engine

By

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Submitted to the College of Engineering
In partial fulfillment of the requirements for the
Bachelor degree in Automotive Engineering

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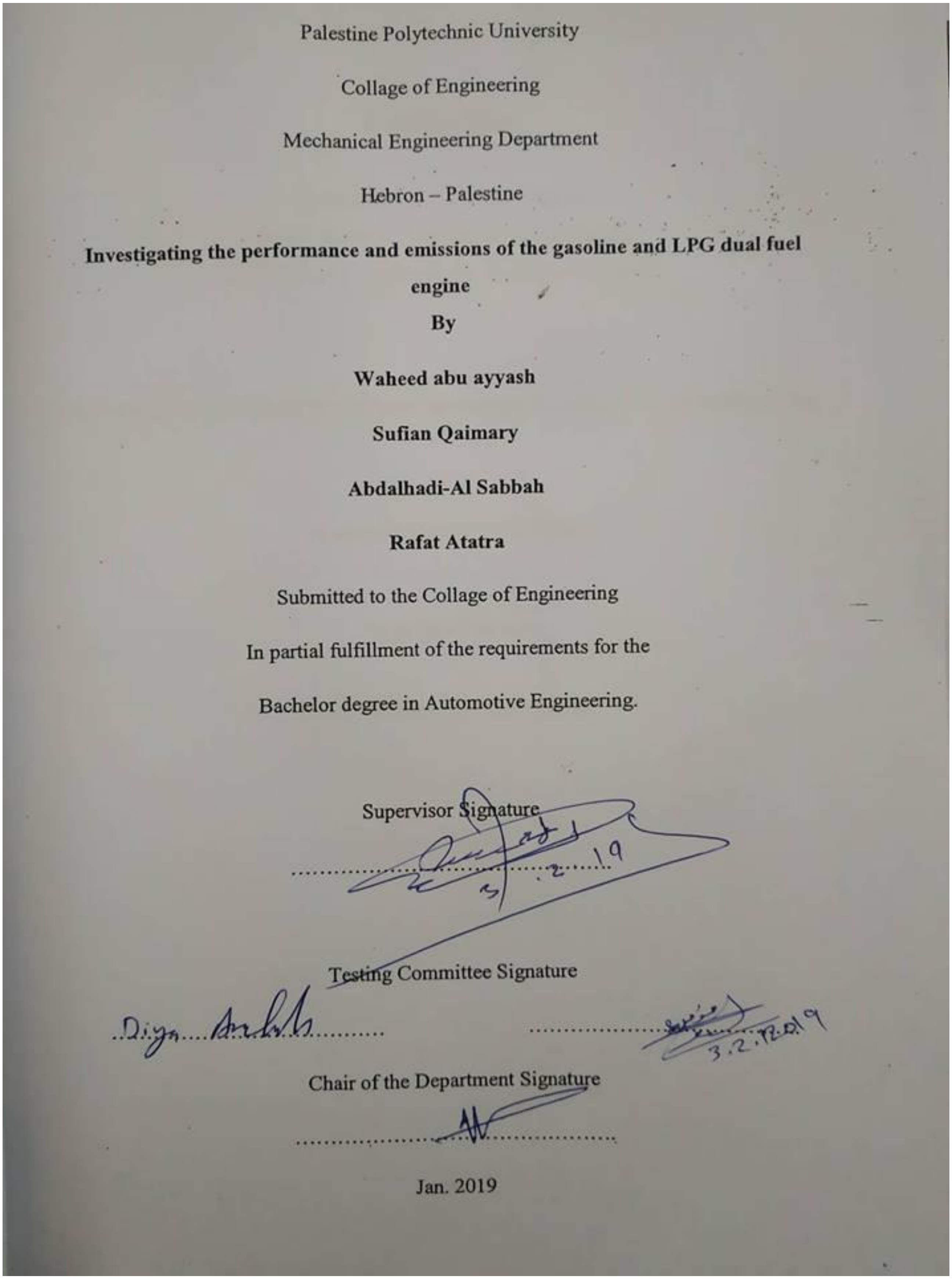

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3.2.2019

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Jan. 2019

Dedication

To our Families … For their support

To our Teachers … For helping us until the end

To our Friends … Who gave us the positive sentiment

To oppressed people throughout the world and their struggle for social justice and egalitarianism

To our supervisor Dr. Zuhdi Salhab

To our great Palestine

To all who made this work possible

Acknowledgment

We would like to express our gratitude for everyone who helped us during the graduation project , starting with endless thanks for our supervisor Dr. Zuhdi Salhab who didn’t keep any effort in encouraging us to do a great job , providing us with valuable information and advices to be better each time .Thanks for the continuous support and kind communication which great effect regarding to feel interesting about what we are working on.

Finally, Thanks are extended to the “Automotive and Mechanical engineering” for the beneficial lectures provided.

Abstract

With the increasing environmental legislation and the increasing demand for the transportation sector, that relies mainly on conventional fuels for operating the engines of its vehicles, as this sector directly affects the environment through emissions comes a big importance and responsibility to focus on the fuels that these engines consume and the emissions it produces.

In this project, the LPG dual fuel engine is studied and offered as an alternative fuel system for the engines to operate on it. Using both alternative fuel Liquefied Petroleum Gas (LPG) and conventional fuel gasoline in Spark ignition engine (SIEs), which is modified to be able to use the Gasoline as a primary fuel to warm up the engine and the LPG with a variation mixture in all time of action. The LPG dual fuel engine has a good thermal efficiency partially for low load and speed, the performance and emissions are mainly varying depending on these two factors, so this fact raises a challenge to reduce the emissions produced as much as possible when using the LPG dual fuel engine with in / out Exhaust Gas Recirculation (EGR) system, which is used to reduce Nitrogen Oxide (NOx), Carbon monoxide (CO).

The approach will be studied and tested theoretically and practically to find the optimal outcome for the LPG dual fuel through this project.

Key words: Gasoline, LPG, dual fuel, Environment, Economy.

مع زيادة التشريعات البيئية وزيادة الطلب على قطاع النقل ، والذي يعتمد بشكل رئيسي على الوقود التقليدي لتشغيل هذه المحركات ، حيث يؤثر هذا القطاع بشكل مباشر على البيئة من خلال الانبعاثات الصادرة من هذه المحركات. في هذا المشروع ، يستخدم محرك الوقود المزدوج كل من وقود البترول المسال البديل (LPG) ووقود البنزين التقليدي في محرك الإشعال بالشرارة (SIEs)، وتعديله ليكون قادر على استخدام غوقود البنزين كوقود أولي لضمان تشغيل المحرك مع وقود البترول المسال بنسب خلط مختلفة طوال فترة تشغيل المحرك، يتمتع محرك الوقود المزدوج بغاز البترول المسال بكفاءة حرارية جيدة خاصة في الحمل والسرعات المتوسطة والقليلة ، ويتفاوت الأداء والانبعاثات أساساً تبعاً لهذين العاملين.

ومع ذلك ، فإن هذه الحقيقة تثير تحديًا لخفض هذه الانبعاثات قدر المستطاع عند استخدام محرك الوقود المزدوج LPG مع نظام إعادة تدوير غاز العادم (EGR) ، والذي تم استخدامه لتقليل أكسيد النيتروجين (NOx) ، أول أكسيد الكربون (CO).

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Chapter 1

Introduction

Chapter 1

1.1 Overview

Environmental concerns and depletion in petroleum resources have been pushing the world to concentrate on finding alternatives to conventional petroleum fuels.

Excessive use of fossil-based fuels exhausts the reserves and also increases the air pollution, these improve the awareness of the effective use of present reserves and slowly switches over to the alternative fuels, which are environment-friendly.

One of the solutions to accomplish this is to use gaseous fuels in addition to the Spark ignition engine (SIE's), the use of alternative gaseous fuels e.g. Natural gas, liquefied petroleum gas (LPG) etc. Is a promising approach for lowering the dependence on petroleum-based liquid fuels and to reduction the emissions of CO_2 and other pollutants from the gasoline engine.[1]

1.2 Importance of the Project

The importance of this project is applying the idea of continuous mixing of fuel during the operation of the vehicle, which helps in reducing fuel consumption and exhaust emissions, providing a promising approach to reduce reliance on petroleum-based liquid fuel.

1.3 Problem Statement

1. The shortage of liquid fuel and the realization that gaseous fuels are far cheaper than liquid fuels have led to attention on dual-fuel engine.
2. Natural gas available to most of part of the world at rates cheaper than liquid fuels.

1.4 Objectives of the Project

1. Running a Spark ignition engine on two types of fuel at the same time.
2. Reduction of fuel consumption.
3. Reduction of exhaust emission.

1.5 Methodology

The methodology of working depends on adding a dual fuel system to a Spark ignition engine (SIEs). So a gasoline engine is being modified to work on two fuels by adding an LPG fuel system in addition to the original gasoline fuel system.

To implement such a project, it’s needed to add every requirement of the LPG fuel system such as pumps, rails, valves, tank, and pipes, and these requirements depend on several parameters and design factors of the engine. Such as cubic capacity and compression ratio.

After considering all of these parameters there will be a need for doing some experiments. Such as performance analysis and analyzing the exhaust gases by using a dynamometer and a gas analyzer to monitor the measurements of power and exhaust emissions.

1.6 Literature review

Combustion Characteristics and Cyclic variation of a LPG fuelled MPFI Four cylinder Gasoline Engine.

Vighnesha Nayak* , Rashmi G.S., Parashuram Chitragar, P. Mohanan. December 2016

Present study deals with to investigate the effect of dual mode of operation on combustion characteristics of engine and cyclic variation in a modified multi-cylinder SI engine. Experiments will be conducted with baseline gasoline and later with dual fuel mode of experiments i.e., gasoline with LPG with different ratios (25%, 50%, 75% and 100% of LPG by mass). Experiment will be carried out with varying speed from 2000 rpm to 4500 rpm in steps of 500 rpm at full load condition with factory set static ignition timing of 5 deg. BTDC to investigate combustion characteristics and cyclic variations. [4]

PERFORMANCE OF GASOLINE/LPG BI-FUEL ENGINE OF MANIFOLD ABSOLUTE PRESSURE SENSOR (MAPS) VARIATIONS FEEDBACK .

Muji Setiyo, Budi Waluyo, Willyanto Anggono and Mohammad Husni. April 2016

This article presents a novel method of changing the ignition curve in an LPG/Gasoline bi-fuel engines which still use the converter and mixer models. The goal of this research was to get the best engine power in fuel operating mode both gasoline and LPG. In order to obtain optimum engine performance in both fuels, there should be two ignition curves, one for gasoline and the other for LPG. A circuit Simple Electronic Spark Module (SESM) was applied to manipulate the feedback voltage from a Manifold Absolute Pressure Sensor (MAPS). A Simple Electronic Spark Module (SESM) to control the ignition timing for bi-fuel engine could produce better engine performance in the two modes of fuel, LPG and gasoline, especially during acceleration and heavy loads. When the engine is running on LPG and the MAPS feedback changes from 1.4 to 1.0 volts and has a significant effect, although in the range of 1.0 to 0.6 volts showed almost the same results, the best maximum power occurred when the MAPS feedback was set at 0.8 volt. In conclusion, the power loss in bi-fuel engines when running on LPG can be corrected by manipulating the MAPS feedback before it is supplied to the ECU.[5]

Performance of Single Cylinder Spark Ignition Engine Fueled by LPG .

Sulaiman, M. Y.^{a},* Ayob, M. Ra and Meran, I.a . February 2013

This paper analyze the characteristics of single cylinder SI ICE fueled by LPG. In particular, torque and engine speed were examined with using the universal dynamometer. In addition to the fuel consumption has been measured to identify which fuel is more practical for SI ICE. SI engine fueled by LPG has slightly decreased on power output up to 4 % compared to unleaded petrol (ULP). However, engine fueled by LPG reduce on specific fuel consumption (SFC) to 28.38 %. In addition, LPG engine have low energy price than ULP engine with difference up to 47.40 %. [6]

Comparative Emission Analysis of Gasoline/LPG Automotive Biofuel Engine. R.R. Saraf, S.S.Thipse and P.K.Saxena. April 2009

This paper presents a comparative emission study of newly introduced gasoline/LPG bifuel automotive engine in Indian market Objectives of this experimental study, were to measure emissions of engines in gasoline & LPG mode and compare them. Engine was run in LPG mode by using conversion system. Emissions were tested as per standard procedure and were compared. Paper describes detail emission test procedure and results obtained. CO emissions were in the range of 38.9 to 111.3 ppm. HC emissions were in the range of 18.2 to 62.6 ppm. Nox emissions were 0.8 to 3.9 ppm and CO2 emissions were from 6719.2 to 8051 ppm. [7]

Investigating the effects of LPG on spark ignition engine combustion and performance.

Hakan Bayraktar *, Orhan Durgun . August 2005

The main idea of this paper is about a spark ignition (SI) engine cycle model which is used to predict the cycle, performance and exhaust emissions of an automotive engine for the cases of using gasoline and LPG. Governing equations of the mathematical model mainly consist of first order ordinary differential equations derived for cylinder pressure and temperature. A computer code for the cycle model has been prepared to perform numerical calculations over a range of engine speeds and fuel–air equivalence ratios. In the computations performed at different engine speeds, the same fuel–air equivalence ratios are selected for each fuel to make realistic comparisons from the fuel economy and fuel consumption points of view. Comparisons show that if LPG fueled SI engines are operated at the same conditions with those of gasoline fueled SI engines, significant improvements in exhaust emissions can be achieved. [8]

1.7 Project Managements.

The project has been managed through a 16 week period in which every part took a certain time to be finished within its period, as shown in the table below.

1.7.1 Time Table for the 2nd part of the project

Table 1. 1 Time Schedule for the Project 2nd part.

Tasks Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Selection of project idea	🟦	🟦	🟦													
Collecting of the data			🟦	🟦	🟦											
Literature Review					🟦	🟦	🟦									
Writing and documentation					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Practical application										🟦	🟦	🟦	🟦			
Prepare the initial version													🟦	🟦	🟦	
Prepare the final version															🟦	🟦

1.7.2 Cost Table

The table below shows the item name and number use and the price per unit

Table 1. 2 The Budget of the Project

Item	Number	Price / unit ($)
Electronic Control Unit (ECU)	1	150
Injectors	4	100
Reducer	1	150
Thermos sensor	2	30
Switch	1	30
Pipes	10	15
Electrical plugs	4	50
Tank	1	150
Valve	1	50
Water pipes	2	30
Multi valve	1	50
Control mechanism	1	50
Total cost	**-**	**1500**

Chapter 2

Characteristics & Calculations

2.1 Introduction

LPG is a mixture between 40% butane (C4H10) and 60% propane (C3H8) having saturated hydrocarbons, LPG is c instead of gasoline, like it was clarified previously. It means that LPG vehicles should be planned and worked for it, or they can be changed over gasoline or diesel vehicles.

A key research objective for the automotive engineering community has been the potential combination of gasoline-engine specific power with diesel-like engine efficiency in a cost-competitive, production-feasible power train.

LPG is obtained from hydrocarbons produced during refining of crude oil and from heavier components of natural gas. It is petroleum derived colorless gas LPG consists of propane or butane or mixtures of both. Small quantities of ethane or pentane may also be present. LPG has high octane rating of 112 RON which enables higher compression ratio to be employed & hence gives higher thermal efficiency. Due to low maintenance cost, economic market price and environment friendly characteristics LPG is becoming popular alternative for gasoline. The main purpose of carrying out this experimental test was to draw a fair comparison between petrol and LPG as fuel in SI engine load testing.

2.2 Physical & Chemical Properties for LPG

2.2.1 Density

The density of LPG is an important feature for quality control in processing and transporting these substances. LPG density is used as a part to transfer quantity calculations, storage, and regulatory requirements. The LPG density is required to allow conversion from mass flow to volume flow measurements.

LPG at atmospheric pressure and temperature is a gas which is 1.5 to 2.0 times heavier than air. It is readily liquefied under moderate pressures. The density of the liquid is approximately half that of water and ranges from 0.525 kg/L to 0.580 kg/L @ 15 deg. C. [11]

2.2.2 Vapor Pressure

The pressure inside an LPG storage vessel. The cylinder will be equal to the vapor pressure corresponding to the temperature of LPG in the storage vessel. The vapor pressure depends on temperature as well as on the ratio of mixture of hydrocarbons.

2.2.3 Combustion

The combustion reaction of LPG increases the volume of products in addition to the generation of heat. LPG requires up to 50 times its own volume of air for complete combustion. Thus it is essential that adequate ventilation is provided when LPG is burnt in enclosed spaces otherwise asphyxiation due to depletion of oxygen apart from the formation of carbon-dioxide can occur.

2.2.4 Calorific Value (CV)

All substances that burn generate energy in the form of heat, which varies in quantity with the nature of the substance. The total amount of heat released by burning a substance is known as its Calorific Value (CV). It is usually expressed (MJ/kg). For LPG, it is 44.097 kg/k mole.[11]

2.2.5 Flash Point

The flash point of LPG (propane) is (-104°C) or (-156°F). This is the minimum temperature at which the propane will burn on its own after ignition. Below this temperature, it will stop burning on its own.[11]

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2.2.6 Flame Temperature

Flame temperature is the temperature that results from a complete combustion process. Its temperature is higher than the constant pressure process because none of the energy is utilized to change the volume of the system. [11]

Table 2. 1 Flame temperature at constant pressure for LPG

Butane	1,970°C (air)
Propane	2,820°C (oxygen), 1,980°C (air)

2.3 Physical & Chemical Properties for Gasoline (Octane)

2.3.1 Density

Octane fuel (C8H18) has included a higher octane number to reduce the knock and octane has a low density that’s given a higher power output and higher fuel consumption.

Knowledge of the original density of a batch of fuel is useful to the injection system and the density of Octane 703 kg/m^3.

2.3.2 Octane Number

Is a measurement of the ignition quality of gasoline. The higher this number, the less knocking when it is burnt in the engine. Octane number denotes the percentage volume of an iso-octane in a combustible mixture whose 'anti-knocking' characteristics match those of the gas being tested.

The most common type of octane rating worldwide is the Research Octane Number (RON). RON is determined by running the fuel in a test engine with a variable compression ratio under controlled conditions and comparing the results with those for mixtures of iso-octane and n-heptane.

2.3.3 Volatility

The fuel should be sufficiently volatile at operating range temperature, which will lead to good start, better warm up and good combustion fuel.

The fuel must have a certain heat vaporization it's good for fuel and increases a volumetric efficiency.

2.4 Heating Value

It’s the amount of energy “heat” released when a fuel is burned completely in the steady flow process and the products are returned to the state of the reaction.

2.4.1 Stoichiometric Equation for Pure Gasoline @ Lamda (λ=1)

$$C_{8.26}H_{15.5} + a_{th}\,(O_2 + 3.76N_2) \rightarrow x\,CO_2 + y\,H_2O + ath\,3.76N_2$$

Can be obtain the values of parameters (x, y, a_{th}) from balancing the equation:

C Balance: $x = 8.26$

H Balance: $2y = 18$ $y = 7.75$

O Balance: $2a_{th} = 2x + y$ $a_{th} = 12.135$

$$\text{Air fuel ratio (A/F)} = \frac{\mathrm{Mass_{air}}}{\mathrm{Mass_{fuel}}} \tag{2.1}$$

$$A/F = \frac{12.135[(2*16)+(2*14*3.76)]}{(12*8)+(18*1)}$$

A/F = 14.53 Kg air / 1 kg fuel

The higher heating value (HHV) and lower heating value (LHV) has been calculated @ 25 °c, 1atm from thermodynamic Appendix A-26 as shown in Table 2.2:

$$\overline{\mathrm{h_c}} = [\ \sum(\mathrm{N\ h})_{\mathrm{fg}_{\mathrm{product}}} - \sum(\mathrm{N\ h})_{\mathrm{fg}_{\mathrm{reactantce}}}\ ] \tag{2.2}$$

$$\overline{\mathrm{h_c}} = [\sum(\mathrm{Nh_{fg}})_{\mathrm{CO2}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{H2O}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{N2}}] - [\sum(\mathrm{Nh_{fg}})_{\mathrm{C8.26H15.5}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{air}}] \tag{2.3}$$

$$\overline{\mathrm{h_c}} = [\sum(\mathrm{Nh_{fg}})_{\mathrm{CO2}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{H2O}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{N2}}] - [\sum(\mathrm{Nh_{fg}})_{\mathrm{C8H18}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{air}}] \tag{2.4}$$

$$\overline{h_c} = [8.26*(-393{,}520) + 7.75*(-241{,}820) + 0] - [1*(-250{,}000) + 0]$$

$\overline{h_c}$ = -5,124,580.2 + 250,000

$\overline{h_c}$= -4,874,580 KJ/Kmol.

$$\text{HHV} = |\overline{\text{h}_\text{c}}| \qquad (2.5)$$

$$\text{LHV} = \frac{\text{HHV}}{\text{M}_{\text{fuel}}} \qquad (2.6)$$

$$\text{LHV} = \frac{|-5{,}512{,}180|}{114.26}$$

LHV = 42.53 MJ/kg fuel. For pure Gasoline @ lambda= 1

2.4.2 Stoichiometric Equation for Pure LPG @ Lamda (λ=1)

$$0.6\ C_3H_8 + 0.4\ C_4H_{10} + \ a_{th}\ (O_2 + 3.76N_2)\ \rightarrow x\ CO_2 + y\ H_2O + ath\ 3.76N_2$$

Can be obtain the values of parameters (x, y, a_{th}) from balancing the equation:

C Balance: $1.8 + 1.6 = x$ $x = 3.4$

H Balance: $4.8 + 4 = 2y$ $y = 4.4$

O Balance: $2a_{th} = 2x + y$ $a_{th} = 11.2$

Air fuel ratio (A/F) = $\frac{\text{Mass}_{\text{air}}}{\text{Mass}_{\text{fuel}}}$

A/F= $\frac{11.2[(2*16)+(2*14*3.76)]}{(0.6[(3*12)+(8)]+0.4[(4*12)+(10)])}$

A/F = 15.49 Kg air / 1 kg fuel

The higher heating value (HHV) and lower heating value (LHV) has been calculated @ 25 ̊c, 1atm:

$$\overline{\text{h}_\text{c}} = [\ \sum(\text{N h})_{\text{fg}_{\text{product}}} - \quad \sum(\text{N h})_{\text{fg}_{\text{reactantce}}}\ ]$$

$$\overline{\text{h}_\text{c}} = [\sum(\text{Nh}_{\text{fg}})_{\text{CO2}} + \sum(\text{Nh}_{\text{fg}})_{\text{H2O}} + \sum(\text{Nh}_{\text{fg}})_{\text{N2}}] - [\sum(\text{Nh}_{\text{fg}})_{\text{C3H8}} + \sum(\text{Nh}_{\text{fg}})_{\text{C4H10}} + \sum(\text{Nh}_{\text{fg}})_{\text{air}}]$$

$\overline{\text{h}_\text{c}}$ = [3.4*(-393,520) + 4.4*(-241820) + 0] – [0.6*(-103,850) + 0.4*(126,150) + 0

$\overline{\text{h}_\text{c}}$ = -2,401,976 + 112,770

$\overline{h_c}$ = -2,289,206 KJ/Kmol.

HHV = $|\overline{h_c}|$

LHV = $\frac{HHV}{M_{fuel}}$

LHV = $\frac{|-2{,}289{,}206|}{49.6}$

LHV = 46.1 MJ/kg fuel. For pure LPG @ lambda =1

2.4.3 Stoichiometric Equation Mixing Between 1 LPG & 1 gasoline @ Lambda (λ=1)

$$0.6\ C_3H_8 + 0.4\ C_4H_{10} + C_{8.26}H_{15.5} + a_{th}\ (O_2 + 3.76N_2) \rightarrow x\ CO_2 + y\ H_2O + ath\ 3.76N_2$$

Can be obtain the values of parameters (x, y, a_{th}) from balancing the equation:

C Balance: 1.8 + 1.6 + 8 = x x = 11.66

H Balance: 4.8 + 4 + 15.5 = 2y y =12.15

O Balance: $2a_{th} = 2x + y$ a_{th} = 17.735

Air fuel ratio (A/F) = $\frac{Mass_{air}}{Mass_{fuel}}$

A/F = $\frac{12.5[(2*16)+(2*14*3.76)]}{(12*8)+(18*1)}$

A/F = 15.05 Kg air / 1 kg fuel.

The higher heating value (HHV) and lower heating value (LHV) has been calculated @ 25 ◌̊c, 1atm:

$$\overline{h_c} = [\ \sum(N\ h)_{fg_{product}} - \quad \sum(N\ h)_{fg_{reactantce}}\ ]$$

$$\overline{\mathrm{h_c}} = [\ \sum(\mathrm{Nh_{fg}})_{\mathrm{CO2}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{H2O}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{N2}}] - [\sum(\mathrm{Nh_{fg}})_{\mathrm{C8.26H15.5}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{C3H8}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{C4H10}} + \sum(\mathrm{Nh_{fg}})_{\mathrm{air}}]$$

$\overline{h_c}$ = [11.4*(-393,520) + 13.4*(285,830) + 0] – [1*(-208,450) + 0.6*(-103,850) + 0.4*(-126,150)]

$\overline{h_c}$ = -7,526,556.2 + 326,770

$\overline{h_c}$ = -7,163,786.2 KJ/kmol

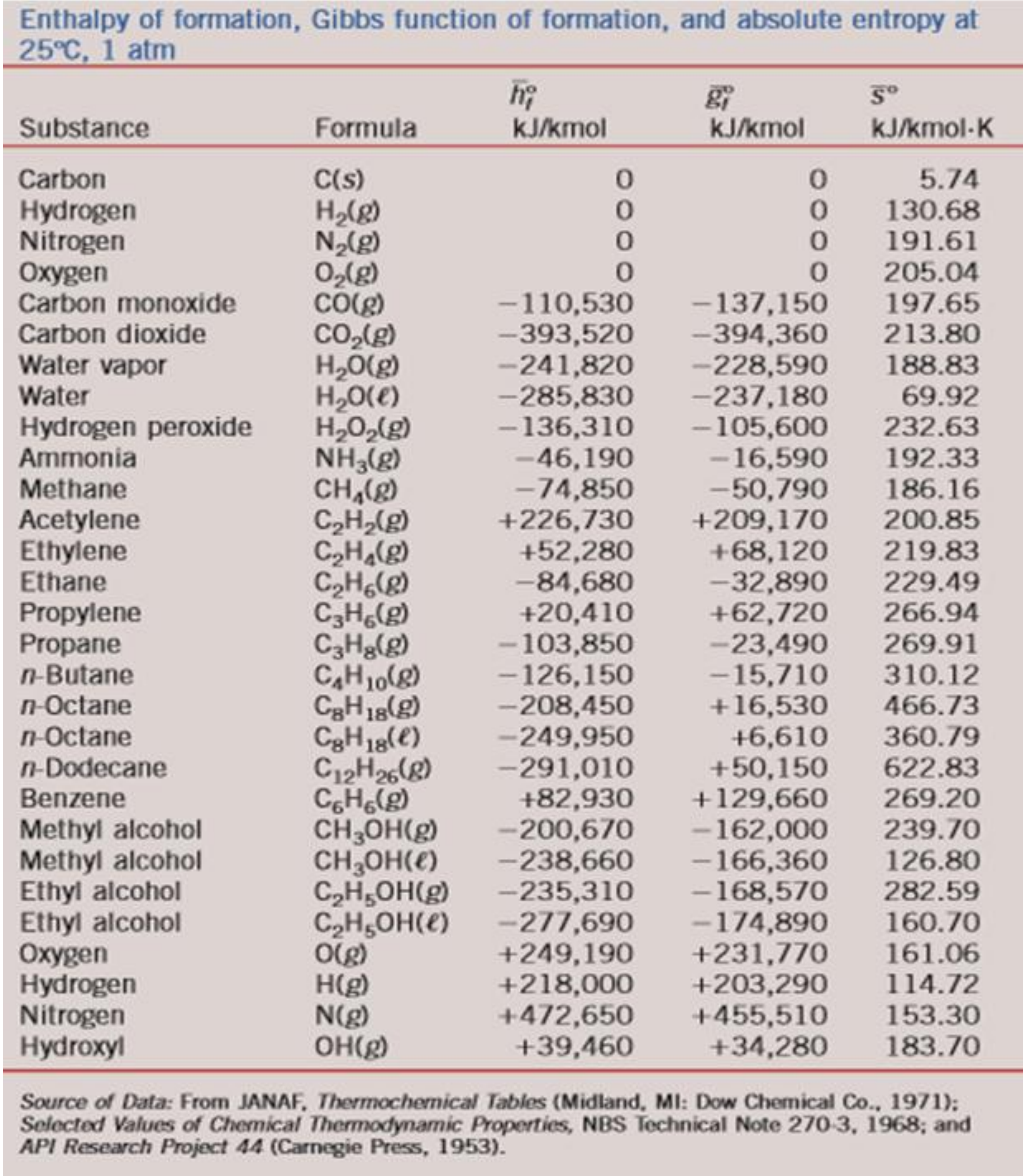
HHV = $|\overline{h_c}|$

LHV = $\frac{\mathrm{HHV}}{\mathrm{M_{fuel}}}$

LHV = $\frac{|-7{,}163{,}786.2\ |}{219.6}$

LHV = 43.26 MJ/kg fuel. For mixing between (1 to 1) LPG to Gasoline

Table 2. 2 thermodynamic table A-26



Enthalpy of formation, Gibbs function of formation, and absolute entropy at 25°C, 1 atm

Substance	Formula	$\bar{h}_f^\circ$ kJ/kmol	$\bar{g}_f^\circ$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol·K
Carbon	$C(s)$	0	0	5.74
Hydrogen	$H_2(g)$	0	0	130.68
Nitrogen	$N_2(g)$	0	0	191.61
Oxygen	$O_2(g)$	0	0	205.04
Carbon monoxide	$CO(g)$	−110,530	−137,150	197.65
Carbon dioxide	$CO_2(g)$	−393,520	−394,360	213.80
Water vapor	$H_2O(g)$	−241,820	−228,590	188.83
Water	$H_2O(\ell)$	−285,830	−237,180	69.92
Hydrogen peroxide	$H_2O_2(g)$	−136,310	−105,600	232.63
Ammonia	$NH_3(g)$	−46,190	−16,590	192.33
Methane	$CH_4(g)$	−74,850	−50,790	186.16
Acetylene	$C_2H_2(g)$	+226,730	+209,170	200.85
Ethylene	$C_2H_4(g)$	+52,280	+68,120	219.83
Ethane	$C_2H_6(g)$	−84,680	−32,890	229.49
Propylene	$C_3H_6(g)$	+20,410	+62,720	266.94
Propane	$C_3H_8(g)$	−103,850	−23,490	269.91
n-Butane	$C_4H_{10}(g)$	−126,150	−15,710	310.12
n-Octane	$C_8H_{18}(g)$	−208,450	+16,530	466.73
n-Octane	$C_8H_{18}(\ell)$	−249,950	+6,610	360.79
n-Dodecane	$C_{12}H_{26}(g)$	−291,010	+50,150	622.83
Benzene	$C_6H_6(g)$	+82,930	+129,660	269.20
Methyl alcohol	$CH_3OH(g)$	−200,670	−162,000	239.70
Methyl alcohol	$CH_3OH(\ell)$	−238,660	−166,360	126.80
Ethyl alcohol	$C_2H_5OH(g)$	−235,310	−168,570	282.59
Ethyl alcohol	$C_2H_5OH(\ell)$	−277,690	−174,890	160.70
Oxygen	$O(g)$	+249,190	+231,770	161.06
Hydrogen	$H(g)$	+218,000	+203,290	114.72
Nitrogen	$N(g)$	+472,650	+455,510	153.30
Hydroxyl	$OH(g)$	+39,460	+34,280	183.70

Source of Data: From JANAF, *Thermochemical Tables* (Midland, MI: Dow Chemical Co., 1971); *Selected Values of Chemical Thermodynamic Properties*, NBS Technical Note 270-3, 1968; and *API Research Project 44* (Carnegie Press, 1953).

Table 2. 3 Calculation for A/F, λ & HV

Calculations Material	A/F (Kg air : Kg fuel)	λ	H.V (MJ/Kg fuel)
Gasoline	14.53 : 1	1	42.53
LPG	15.49 : 1	1	46.15
Mixing @ 1 LPG & 1 Gasoline	14.83: 1	1	43.62
Mixing@ 0.9 LPG & 0.1 Gasoline	15.34 : 1	1	45.27
Mixing@ 0.85 LPG & 0.15 Gasoline	15.28 : 1	1	45.03
Mixing@ 0.6LPG & 0.4 Gasoline	14.91 : 1	1	43.34

What the results tell?

The results mean it's the amount of heat released when fuel is combusted and the products are returned to the state of reactants. And this is an indication to the change in heating value for different mixing ratios

Chapter 3

Sequential Injection System

3.1 Introduction.

3.2 Conversion Kit.

- **3.2.1 Electronic Control System.**
- **3.2.2 Injector Rail.**
- **3.2.3 Reducer.**
- **3.2.4 Manifold Absolute Pressure (MAP) Sensor.**
- **3.2.5 Pressure Gauge.**
- **3.2.6 Gas Filter.**
- **3.2.7 Gas Tank.**
- **3.2.8 Changeover Switch.**
- **3.2.9 Gas Pipe.**
- **3.2.10 Sensors.**

3.3 Technical Specifications.

3.1 Introduction

With petrol prices increasing so often, it makes sense to convert your petrol car to a bi-fuel one that runs on either petrol or LPG or in a dual fuel LPG & gasoline. The process of running a car on a dual fuel LPG & gasoline is fairly demanding and requires a good knowledge of automotive systems in general to accomplish. The dual fuel LPG & gasoline is very safe as an automotive fuel but if the system is not installed correctly, there can be safety problems.

So in in this project, mimgas LPG kit as shown in Fig 3. 1 was chosen to work on because it's very simple, reliable and you can modify on it very easily.

Fig 3. 1 The Sequential Injection System. [10]

3.2 Conversion Kit

3.2.1 Electronic Control System (ECU)

ECU is the brain of the system, it controls all of the functioning of the system and serves several functions as shown in Fig 3. 2, which include regulating and maintaining the amount of fuel and air-fuel mixture in the fuel injection part and helps in increasing horsepower of the engine.

Fig 3. 2 Mimgas Electronic Control Unit (ECU).

3.2.2 Injector Rail

Sequential injector kits come with an injector rail that carries the LPG gas supplied to individual injectors as shown in Fig 3.3, the air-fuel mixture is prepared in the intake manifold and fed to the cylinder for combustion. The fuel injectors mounted on the fuel rail continuously doses the required fuel quantity into the intake manifold according to the spray pattern and with the highest precision.

Fig 3.3 Mimgas Injector Rail.

3.2.3 Reducer

As shown in Fig 3.4 that shows the reducer and main part, the reducer normally has two major functions. The first is to transform the liquid LPG to LPG vapor. The second is to regulate the amount of LPG that goes to the engine. It tries to keep the mixture at the optimum mixture.

The reducer has a shot off valve that's work when engine stop and whenever happened any issue in the system the reducer cut off fuel by controlling the relay to close the solenoid valve.

The reducer supply by a warm water and a thermistor sensor that's to prevents air locks in the reducer and makes it self-bleeding and its supply by a heat solenoid to protect the system.

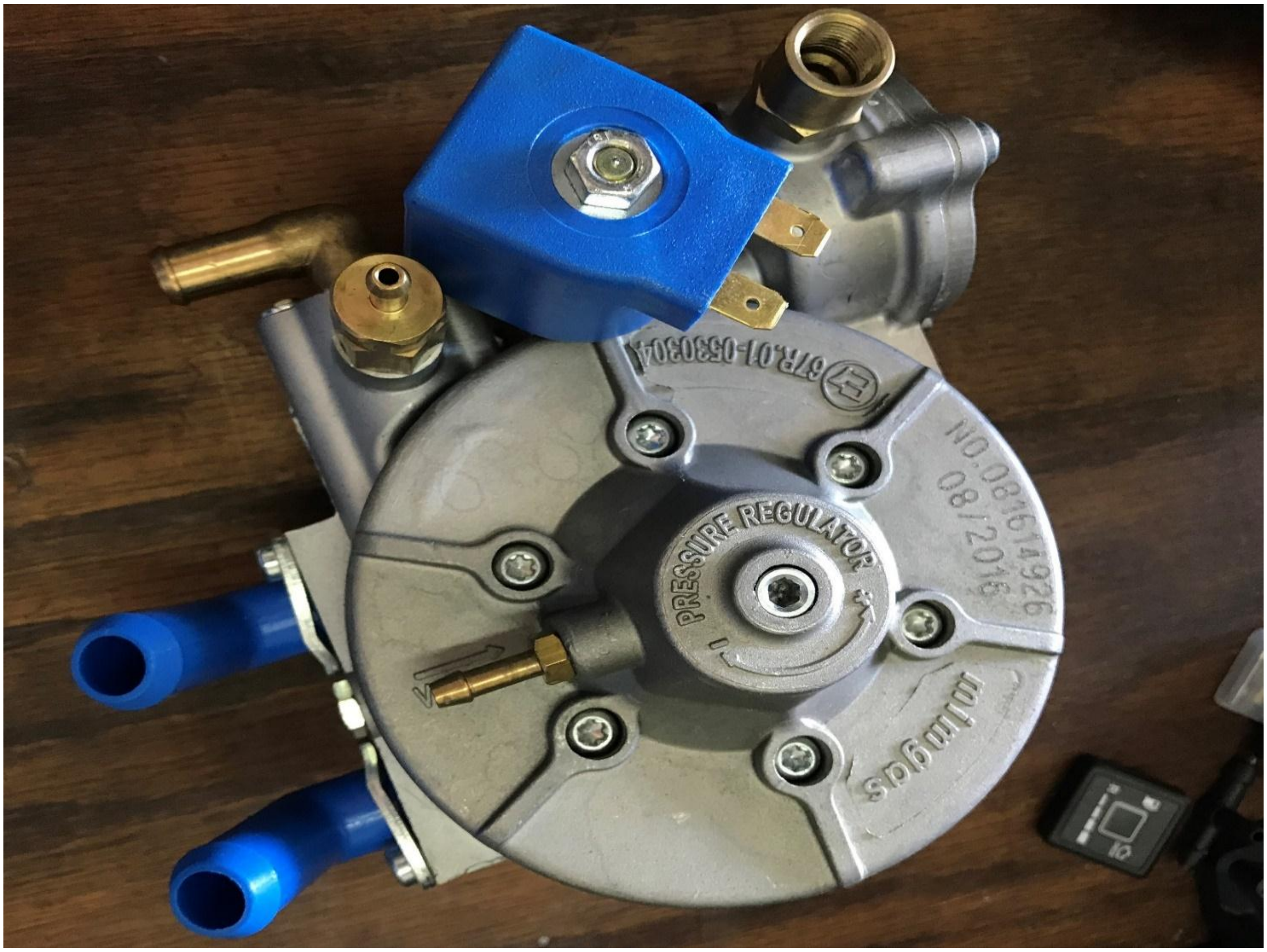


Fig 3. 4 Mimgas Reducer LPG.

3.2.4 Manifold Absolute Pressure (MAP) Sensor

The MAP sensor as shown in Fig 3.5 provides instantaneous manifold pressure information to the engine's (ECU). A fuel-injected engine may alternatively use a mass airflow sensor (MAF sensor) to detect the intake airflow.

Fig 3.5 Mimgas MAP Sensor.

3.2.5 Pressure Gauge

Pressure gauge as shown in Fig 3.6 that is fitted on the tank, which will tell you the amount of LPG that has been filled in it. Which also prevents the tank from overfill.

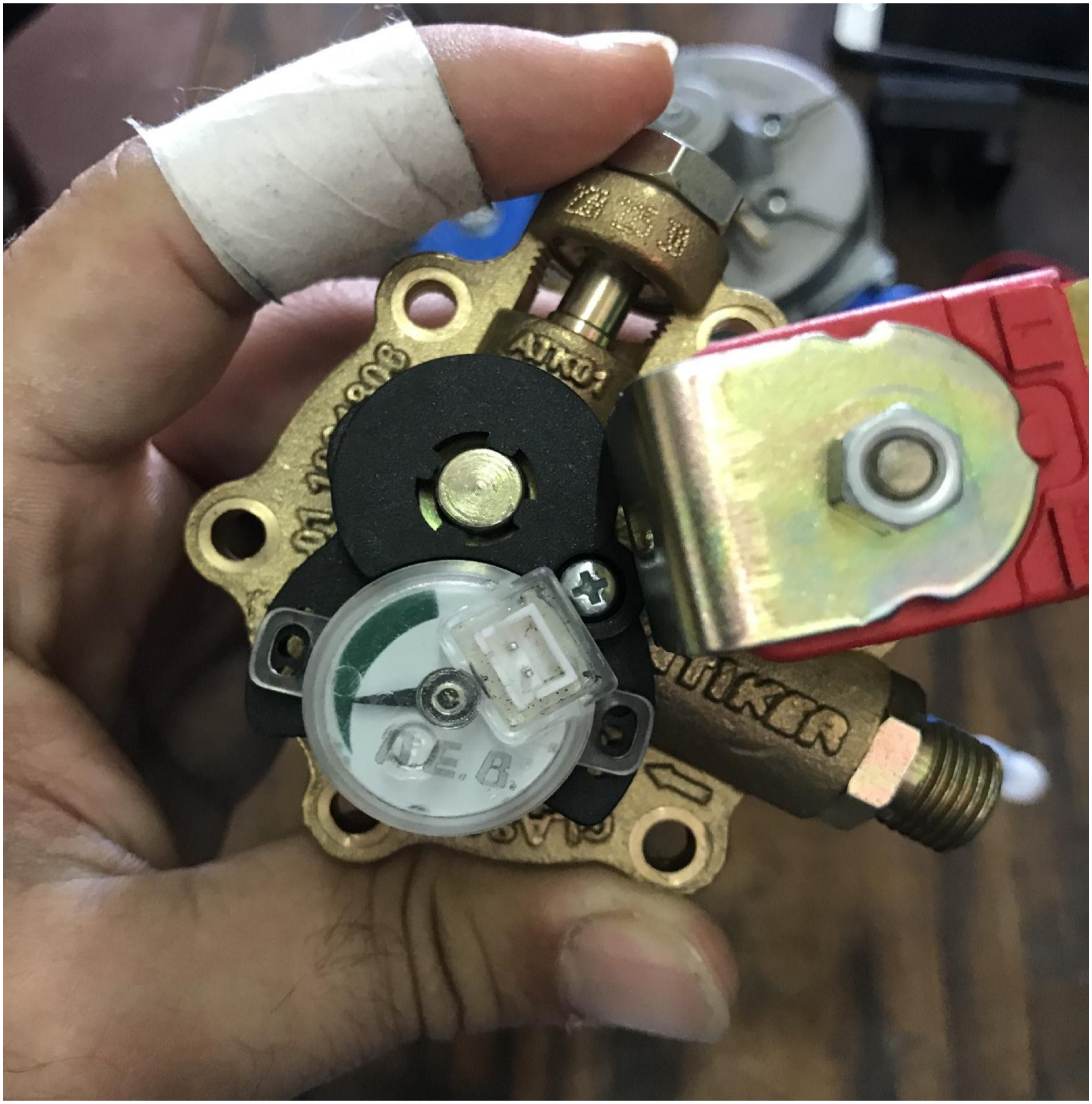


Fig 3.6 Mimgas Pressure Gauge.

3.2.6 Gas Filter

The gas filter as shown in Fig 3.7 is a device that filtrates the gas going to the engine. Sometimes it is replaced with a second safety solenoid to cut off the gas flow going to the engine in the emergency case.

Fig 3.7 Mimgas Gas Filter.

3.2.7 Gas Tank

The most critical aspect of an LPG conversion is choosing the size of tank that will fit in the project's boot. LPG is a heavy gas, and in the case of leakage it will settle around the vehicle increasing the risk of fire. Hence it is important to get a proper branded tank that's securely installed. There are two kinds of tanks available – the cylindrical tank and the toroidal tank. The latter fits in the spare wheel well in the boot of the car, but the boot does not have much capacity. The cylindrical tanks as shown in Fig 3.8 come in 35-litre, 45-litre and 60-litre capacity. The choice of the tank depends on how much space you have in your boot.

In the best of cases, these tanks won't be able to hold the full amount of LPG (which is a liquid when stored). It can hold only about 85% of the capacity at best, depending on the pressure it is filled in and to maintain a safety margin for expansion.

Fig 3.8 Mimgas Gas Tank.

3.2.8 Gas Pipe

The gas pipe as shown in Fig 3.9 is an important component of the kit. It is made out of a strong copper tube that transfers gas (in liquid form) from the LPG reservoir to the engine bay. This pipe needs to be very reliable to prevent leakage, and the installer must be aware not to route this pipe close to the exhaust system or around any electrical components that can cause a fire.

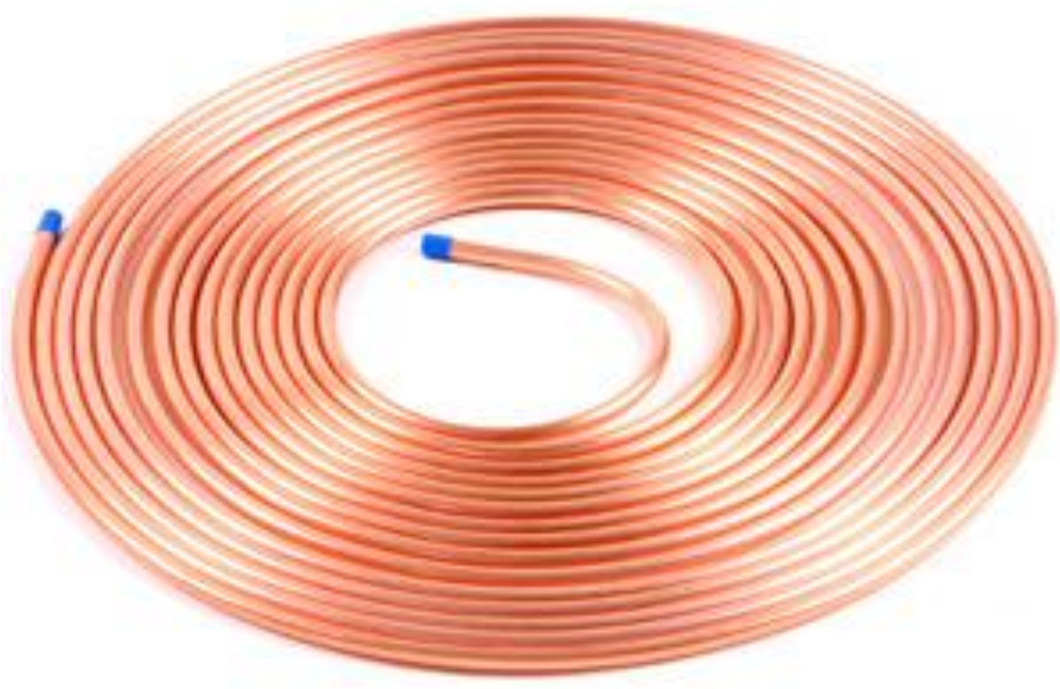


Fig 3.9 Mimgas Gas Pipe.

3.2.9 Changeover Switch

The changeover switch as shown in Fig 3.10 is located in the cabin for the driver to operate. It switches between petrol and gas. When the car is operating on gas alone, this changeover switch will deactivate the petrol fuel pump, shutting off petrol supply to the engine, allowing only gas and vice versa. Changeover switches also act as a gas-fuel gauge by indicating the level of gas in the tank.

Fig 3.10 Mimgas Changeover Switch.

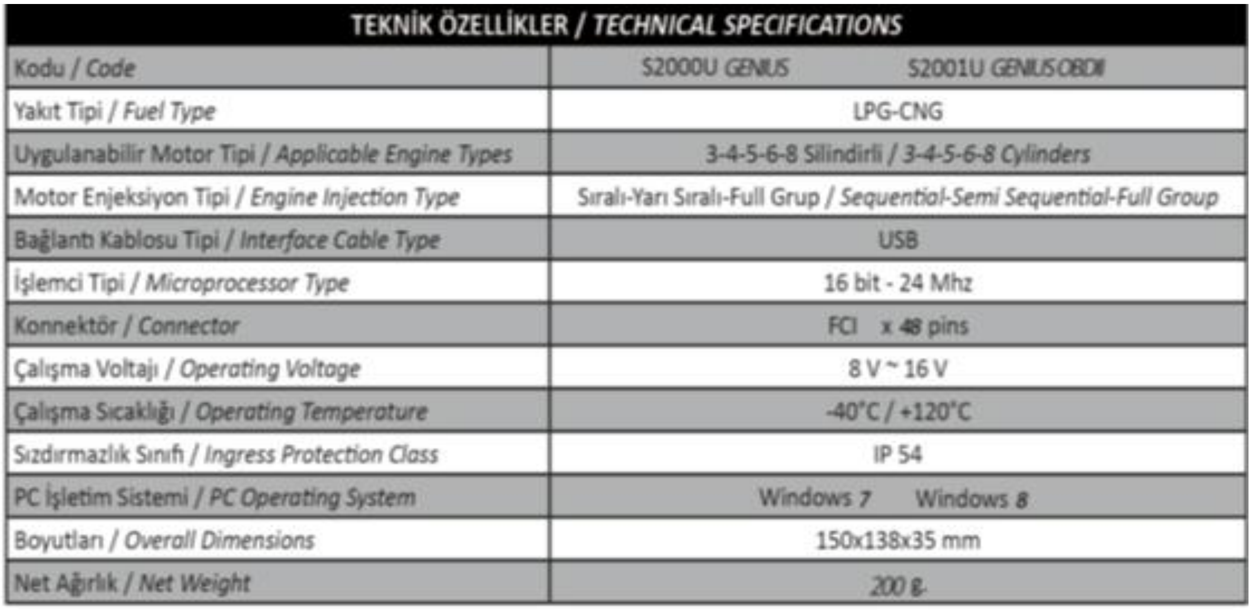
3.2.10 Sensors

There are three sensors that come with the kit as shown in Fig 3.11 that tells the ECU what to do with the gas flow. One is the MAP or manifold absolute pressure sensor. It measures the gas pressure in the intake manifold (which supplies the air-fuel mix to the engine). The second sensor senses the gas pressure in the gas injector rail and tells the ECU to regulate gas injection times. The third is the gas-temperature sensor that checks the temperature of the gas, used by the ECU to control gas volume.

Fig 3.11 Mimgas Sensors.

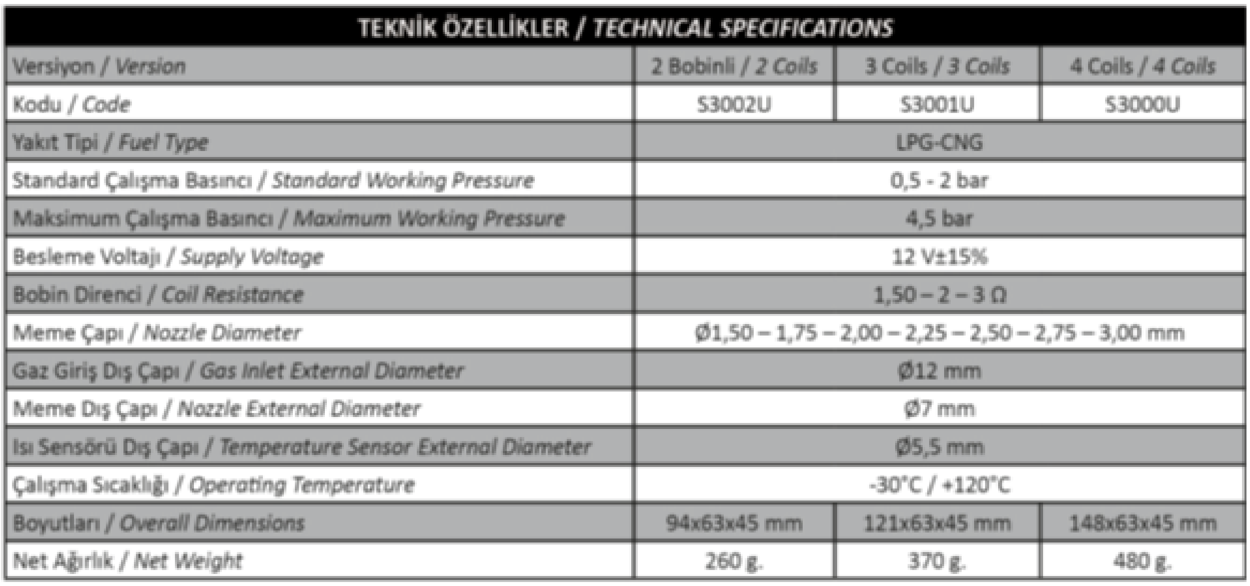
3.3 Technical Specifications

A technical specification document defines the requirements for a project, product, or system. A specification is the information on technical design, development, and procedures related to the requirements it outlines as shown in Fig 3.12 - Fig 3.16. This document provides information to developers and other stakeholders on business requirements, internal standards, and best practices.



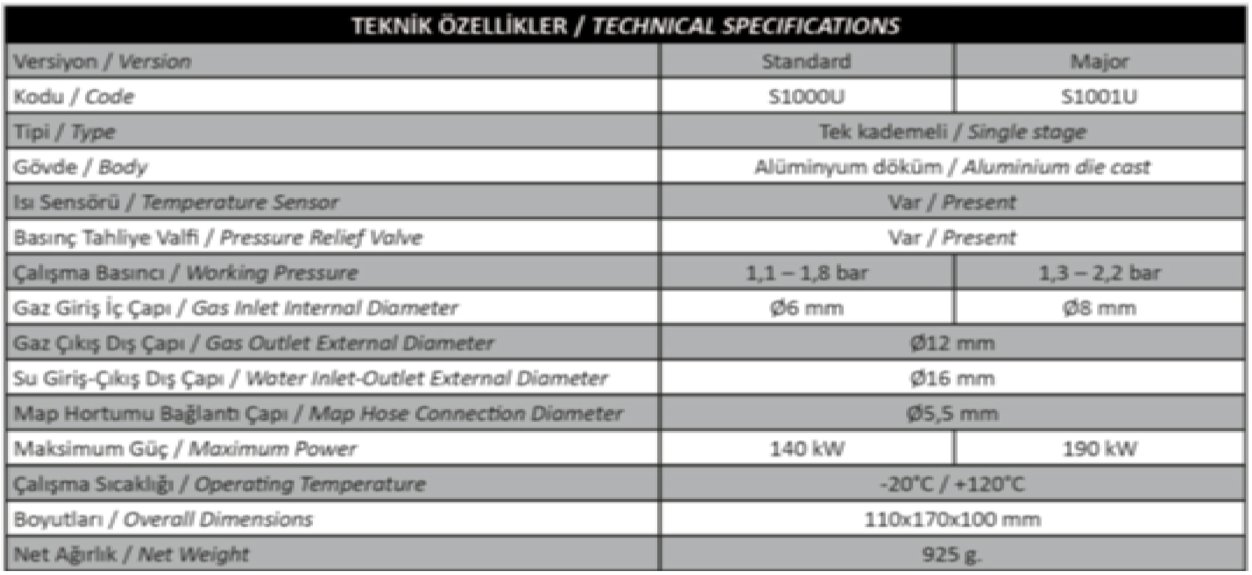
TEKNİK ÖZELLİKLER / *TECHNICAL SPECIFICATIONS*	
Kodu / *Code*	S2000U *GENIUS* S2001U *GENIUS OBDII*
Yakıt Tipi / *Fuel Type*	LPG-CNG
Uygulanabilir Motor Tipi / *Applicable Engine Types*	3-4-5-6-8 Silindirli / *3-4-5-6-8 Cylinders*
Motor Enjeksiyon Tipi / *Engine Injection Type*	Sıralı-Yarı Sıralı-Full Grup / *Sequential-Semi Sequential-Full Group*
Bağlantı Kablosu Tipi / *Interface Cable Type*	USB
İşlemci Tipi / *Microprocessor Type*	16 bit - 24 Mhz
Konnektör / *Connector*	FCI x 48 pins
Çalışma Voltajı / *Operating Voltage*	8 V ~ 16 V
Çalışma Sıcaklığı / *Operating Temperature*	-40°C / +120°C
Sızdırmazlık Sınıfı / *Ingress Protection Class*	IP 54
PC İşletim Sistemi / *PC Operating System*	Windows *7* Windows *8*
Boyutları / *Overall Dimensions*	150x138x35 mm
Net Ağırlık / *Net Weight*	*200 g.*

Fig 3. 12 Mimgas Technical Specification for (ECU). [10]



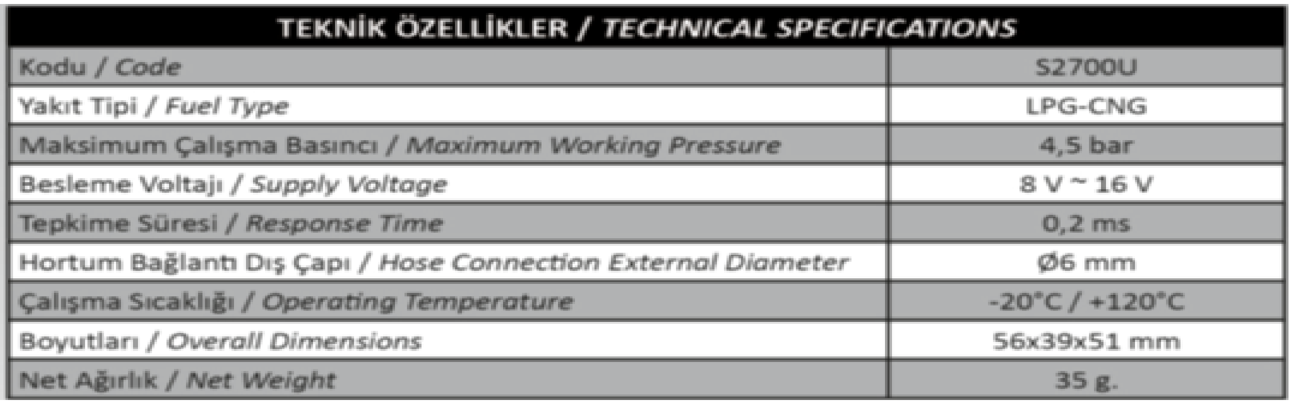
TEKNİK ÖZELLİKLER / *TECHNICAL SPECIFICATIONS*			
Versiyon / *Version*	2 Bobinli / *2 Coils*	3 Coils / *3 Coils*	4 Coils / *4 Coils*
Kodu / *Code*	S3002U	S3001U	S3000U
Yakıt Tipi / *Fuel Type*	LPG-CNG		
Standard Çalışma Basıncı / *Standard Working Pressure*	0,5 - 2 bar		
Maksimum Çalışma Basıncı / *Maximum Working Pressure*	4,5 bar		
Besleme Voltajı / *Supply Voltage*	12 V±15%		
Bobin Direnci / *Coil Resistance*	1,50 – 2 – 3 Ω		
Meme Çapı / *Nozzle Diameter*	Ø1,50 – 1,75 – 2,00 – 2,25 – 2,50 – 2,75 – 3,00 mm		
Gaz Giriş Dış Çapı / *Gas Inlet External Diameter*	Ø12 mm		
Meme Dış Çapı / *Nozzle External Diameter*	Ø7 mm		
Isı Sensörü Dış Çapı / *Temperature Sensor External Diameter*	Ø5,5 mm		
Çalışma Sıcaklığı / *Operating Temperature*	-30°C / +120°C		
Boyutları / *Overall Dimensions*	94x63x45 mm	121x63x45 mm	148x63x45 mm
Net Ağırlık / *Net Weight*	260 g.	370 g.	480 g.

Fig 3.13 Mimgas Technical Specification for the Injection Rail. [10]



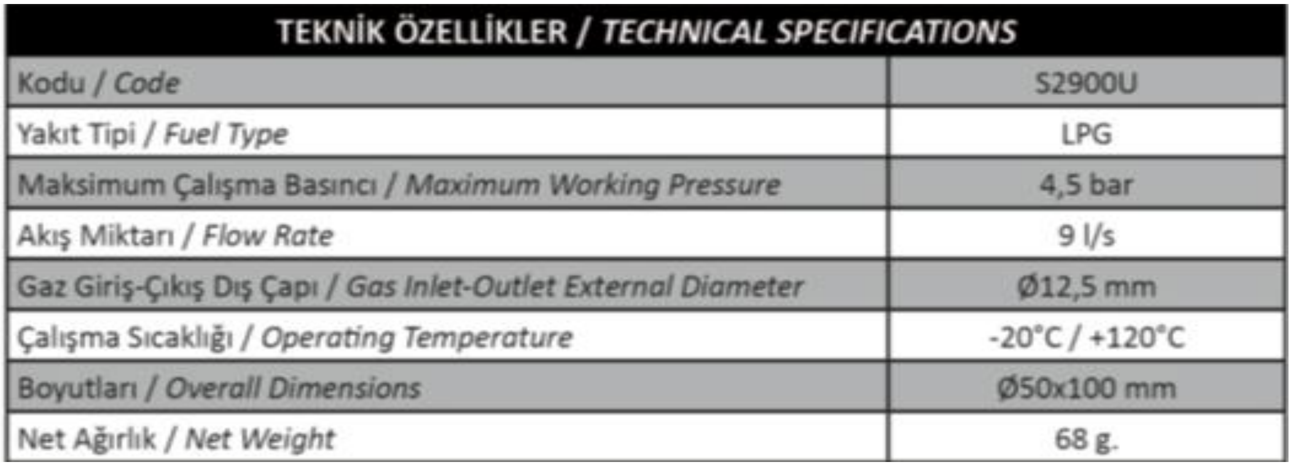
TEKNİK ÖZELLİKLER / *TECHNICAL SPECIFICATIONS*		
Versiyon / *Version*	Standard	Major
Kodu / *Code*	S1000U	S1001U
Tipi / *Type*	Tek kademeli / *Single stage*	
Gövde / *Body*	Alüminyum döküm / *Aluminium die cast*	
Isı Sensörü / *Temperature Sensor*	Var / *Present*	
Basınç Tahliye Valfi / *Pressure Relief Valve*	Var / *Present*	
Çalışma Basıncı / *Working Pressure*	1,1 – 1,8 bar	1,3 – 2,2 bar
Gaz Giriş İç Çapı / *Gas Inlet Internal Diameter*	Ø6 mm	Ø8 mm
Gaz Çıkış Dış Çapı / *Gas Outlet External Diameter*	Ø12 mm	
Su Giriş-Çıkış Dış Çapı / *Water Inlet-Outlet External Diameter*	Ø16 mm	
Map Hortumu Bağlantı Çapı / *Map Hose Connection Diameter*	Ø5,5 mm	
Maksimum Güç / *Maximum Power*	140 kW	190 kW
Çalışma Sıcaklığı / *Operating Temperature*	-20°C / +120°C	
Boyutları / *Overall Dimensions*	110x170x100 mm	
Net Ağırlık / *Net Weight*	925 g.	

Fig 3.14 Mimgas Technical Specification for the Reducer. [10]



TEKNİK ÖZELLİKLER / *TECHNICAL SPECIFICATIONS*	
Kodu / *Code*	S2700U
Yakıt Tipi / *Fuel Type*	LPG-CNG
Maksimum Çalışma Basıncı / *Maximum Working Pressure*	4,5 bar
Besleme Voltajı / *Supply Voltage*	8 V ~ 16 V
Tepkime Süresi / *Response Time*	0,2 ms
Hortum Bağlantı Dış Çapı / *Hose Connection External Diameter*	Ø6 mm
Çalışma Sıcaklığı / *Operating Temperature*	-20°C / +120°C
Boyutları / *Overall Dimensions*	56x39x51 mm
Net Ağırlık / *Net Weight*	35 g.

Fig 3.15 Mimgas Technical Specification for the MAP Sensor. [10]



TEKNİK ÖZELLİKLER / *TECHNICAL SPECIFICATIONS*	
Kodu / *Code*	S2900U
Yakıt Tipi / *Fuel Type*	LPG
Maksimum Çalışma Basıncı / *Maximum Working Pressure*	4,5 bar
Akış Miktarı / *Flow Rate*	9 l/s
Gaz Giriş-Çıkış Dış Çapı / *Gas Inlet-Outlet External Diameter*	Ø12,5 mm
Çalışma Sıcaklığı / *Operating Temperature*	-20°C / +120°C
Boyutları / *Overall Dimensions*	Ø50x100 mm
Net Ağırlık / *Net Weight*	68 g.

Fig 3.16 Mimgas Technical Specification for the Filter. [10]

Chapter 4

Operation of Combustion

4.1 Introduction.

4.2 Gasoline Engines Modification.

4.3 LPG–Gasoline Dual Fuel Operation.

4.4 Control methodology.

4.5 Knocking Phenomenon.

Chapter 4

4.1 Introduction

All Internal Combustion (IC) reciprocating engines operate by the same basic principles (process). A combustible mixture, first, is compressed in a small volume between the head of a piston and its surrounding cylinder. The mixture is then ignited and the produced high-pressure pushes the piston through the cylinder.

Two ignition methods are used in reciprocating IC engines; Compression Ignition (CI) and Spark Ignition (SI). The already implemented method for operation of gasoline engines is by spark Ignition method. In this method the mixture is interred to the cylinder. Then, at the end of the compression stroke, the spark is directly ignited the mixture at high pressure over the compressed mixture inside the combustion chamber.

Meanwhile, the LPG–Gasoline dual fuel engine utilizes the concept of ignition and spark ignition principles. This principle are employed, here, to trigger the ignition of the mixture consists of primary gaseous (LPG) fuel and liquid pilot fuel.

4.2 Gasoline Engines Modification

Gasoline engines can be readily, configured to run on LPG–Gasoline dual fuel mode. Where LPG is mixed into the air intake, while the normal gasoline fuel injection system still supplies a certain amount of gasoline fuel but at a reduced rate. The engine has to be modified to work in the dual fuel mode by establishing an LPG line to the manifold intake along with an evaporator.

Gaseous fuel flows through the regulating valve into the gas mixer assembled on the manifold intake. The design of gaseous fuel supply system has a significant influence on NOx and CO2 emissions at light load, where LPG is supplied to intake manifold by the small duct in the Supply of the LPG into the engine is accompanied by mechanical or electronic control for various loads and speed of engine.

The combustion process and engine output will vary depending on, firstly the type of the engine (direct injection or port injection). Secondly the gaseous fuel supply system. The mass flow rate of LPG is in proportion to the pressure difference between the gas mixer and the evaporator, where the pressure is maintained nearly same as atmospheric pressure.

It is very critical, in LPG dual fuel engines, to control the flow rate of the primary LPG fuel and gasoline fuel at different engine operating conditions. Lower LPG will not contribute in reducing NOx emission nor in improving performance. Meanwhile, higher LPG will, rapidly increase the pressure inside the cylinder and damage the engine.

LPG–Gasoline dual fuel engines were investigated through many researches, of which modification of single cylinder and multi cylinder. Moreover, studies in which the LPG is supplied in the dual fuel mode by manifold injection and manifold induction.

It was found that the combustion, performance and emission characteristics of LPG–Gasoline dual fuel engine depend on the type of the engine, LPG fuel supply system and engine operating conditions. [9]

4.3 LPG–Gasoline Dual Fuel Operation

In case of LPG–Gasoline dual fuel engine, the LPG mixture (from the intake) is drawn into the cylinder, just as it would be in a spark-ignited engine. This mixture is compressed in order to increase the temperature and pressure and at the end of the compression stroke, the mixture is ignited by the spark as will in gasoline engines as shown in Fig. 4.1. [4]

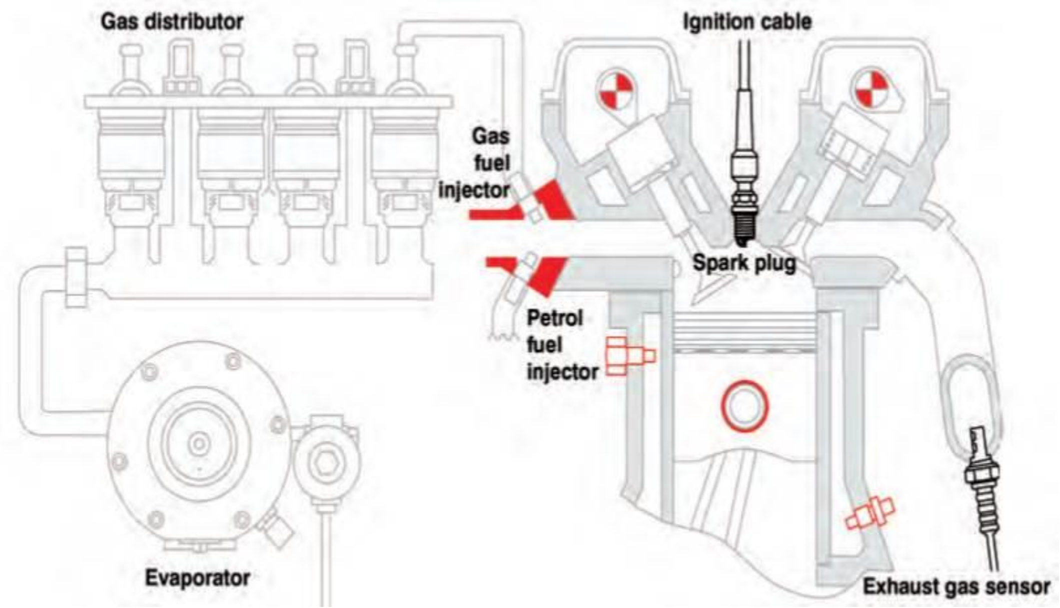


Fig 4. 1 LPG–Gasoline Dual Fuel

The source of ignition to the LPG–Gasoline dual fuel is a spark plug. The operation of combustion happens as it follows: the LPG-air mixture is mixed with a gasoline fuel, and that depends on the type of engine (direct injection or port injection).

It is interesting to note that, in a dual-fuel engine, the combustion process starts in a fashion similar to the spark ignition engine (SIEs).The output power of the engine is normally controlled by changing, the quantity of gasoline fuel used (the amount of primary LPG gaseous fuel added to inlet of manifold) will be varied depending upon the engine operating conditions and its design parameters. Generally, the amount of gasoline injection required for the ignition is between 10% and 20% of that required by operation of the conventional gasoline engine.

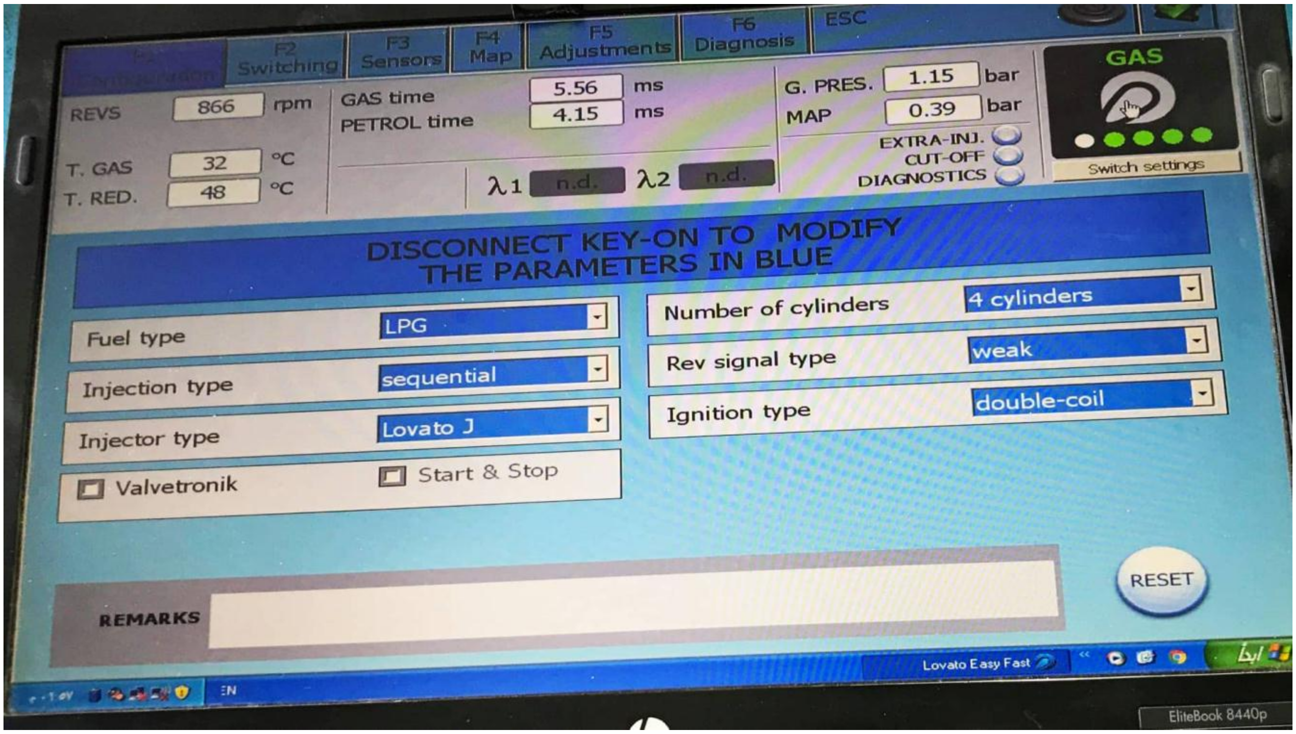
At normal working loads the mass fraction of the LPG used in dual fuel mode is calculated by using the following expression:

$$\boldsymbol{Z} = \frac{\mathrm{M}_{\mathrm{LPG}}}{(\mathrm{M}_{\mathrm{LPG}} + \mathrm{M}_{\mathrm{gasoline}})} \tag{4.1}$$

Where ($M_{gasoline}$) is mass flow rate of gasoline and (M_{LPG}) is mass flow rate of LPG.

And Z= 0% represents gasoline operation, Z= 10%, 20%, 30%, 40% represent the LPG mass fraction used in dual fuel mode. [2]

4.4 Control methodology



REVS 866 rpm
GAS time 5.56 ms
PETROL time 4.15 ms
G. PRES. 1.15 bar
MAP 0.39 bar
T. GAS 32 °C
T. RED. 48 °C
λ1 n.d. λ2 n.d.

DISCONNECT KEY-ON TO MODIFY THE PARAMETERS IN BLUE

Fuel type: LPG
Injection type: sequential
Injector type: Lovato J
☐ Valvetronik
☐ Start & Stop
Number of cylinders: 4 cylinders
Rev signal type: weak
Ignition type: double-coil
REMARKS

Fig 4. 2 Open time Injectors controlling

To achieve the main purpose of this project, it's by controlling and calibrate the (ECU) to the work on different mixing of dual fuel it's taken a lot of input variables and process this input helped the process to decide and determine the correct mixing, this process can be translated in thermodynamic analyses as shown in equations. [4]

The two zones considered in the present analysis are analyzed by applying the first law of thermodynamics and the law of conservation of mass. The burnt zone receives the mass as well as the energy because of the entrainment and the pilot fuel injection. Therefore, the mass of each zone can be obtained by modeling the fuel spray as well as the entrainment process between the pilot fuel and the surrounding gaseous fuel-air mixture. The total mass of the charge inside the cylinder can be calculated using the law of conservation of mass. [4]

$$M = m_u + m_b \quad (4.2)$$

Where mb is the mass of the burnt charge and mu is the mass of the un-burnt charge. When the injection starts mb=0,

$$M\ u = m_{LPG} + m_{air} + m_{residual} \quad (4.3)$$

Where m_{LPG}, m_{air}, $m_{residual}$ are the mass of LPG, air and the residual gases respectively inside the cylinder at the start of the compression process in each cycle. As the injection continues the mass of the burnt zone will increase. At any instant i, the mass of the burnt zone is the sum of the cumulative fuel injected (m inj. i) and the cumulative mass of the surrounding gasses (mentr i) entrained from the un-burnt zone is given by:

$$m = m_{inj\ i} + m\ b_{entr\ i} \quad (4.4)$$

Since two zones are considered inside the combustion chamber the volume constraint at any instant is given by:

$$V = V_{ui} + V_{bi} \quad (4.5)$$

Where Vi is the total volume of the combustion chamber at any instant i, Vui is the volume of the unburnt charge at the instant i, Vbi is the volume of burnt charge at the instant i the equation for the first law of thermodynamics written separately for the burnt and the un-burnt zone are:

$$dU_b = dQp - P\ dVp + dmu\ hu + dm_{fb} \qquad (4.6)$$

$$dU_{ub} = dQ_{ub} - Pd\ Vu + dmu\ hu \qquad (4.7)$$

Where dU_b and dU_{ub} are the change in internal energies of the burnt and the un-burnt zones, dQ_b and dQ_{ub} are the heat transfer from the burnt and the unburnt charges to the cylinder walls, $d_{mu}\ h_u$ is the total enthalpy addition to the burnt zone due to the entrained mass of air, LPG and the residual gases from the un-burnt zone and also represents the loss of enthalpy for the un-burnt zone in the given crank angle duration. P d_{Vb} represents the work done by the burnt zone for the same crank angle. Using the above two equations (5) & (6), and by considering the variable specific heats for the 11 products of combustion using Olikera model at each crank angle along with the volume constraints, the temperature of burnt, un-burnt charges as well as cylinder pressure can be obtained. [4]

4.5 Knocking Phenomenon

The Dual fuel engine is more complex than the ordinary Otto or Diesel engine because it is a hybrid between two fuels.

In SI engines the knock is known as end gas knock. When the flame propagates in the combustion chamber the pressure and temperature outside the flame starts to rise. If the temperature and pressure in the gas mixture outside the flame gets too high, the gas can auto ignite before the flame reaches the outer part of the combustion chamber. This produces heavy pressure oscillations in the cylinder that could damage the engine.

Pre-ignition can occur where there is a hot spot in the combustion chamber from where the flame starts to burn. When this happens too early, the cylinder pressure rises too fast and maximum cylinder pressure becomes too high. Pre-ignition is sometimes the reason for end gas knock.

The knock phenomenon in a dual fuel engine is different than usual SI knock. In this it has been found that both end gas knock and pre-ignition can be a problem. [9]

To avoid knock in the engine.

1. Use of cold combustion air.
2. Increasing the cooling of piston.
3. Reducing the pressure of the gaseous fuel.

Chapter 5

Experimental setup

5.1 Introduction

In any project the best way to observe and get accurate results is by doing a physical experiment, so an experiment has been done to get the closest approach of the idea and outcomes wanted and also goals from this project. Which are studying the effect of different mixing ratios between two fuel types on the performance and emissions of a dual fuel engine, throughout different cases of operating conditions.

Then the behavior of the engine has been observed through each case of operating condition, by using a dynamometer and gas analyzer, to measure engine torque, power and emissions and a conversion kit to be added to the engine, so it can be able to use both fuels depending on a different ratios of mixing between the two types of fuels, that has been used in this project which are gasoline and LPG and to achieve the goal of different mixing ratios a control module in the conversion kit has been modified and controlled by using a Mimgas conversion kit.

Finally the results of the experiment has been recorded on a shape of (X, Y) relation upon a graph so each graph X has been considered as the main variable which is engine speed in (rpm) and Y has been considered as other parameters that affected by the power throughout the different operating conditions cases that the engine has been through.

5.2 Methodology

This experimental performance requires auxiliary instruments to support this test. Since there was an implementation of gas injection in the system, additional measures were taken to adhere to those practices. Few of the basic modifications that was done on the SI engine were:

5.2.1 Fitting of Nozzle on Intake Manifold

The nozzle along with the solenoid operated injection setup was casted at the intake manifold as shown in Fig. 5. 1. By doing this the fuel will directly open up into the intake manifold and hence will result in superior output. The nozzle was fitted by multi drilling in the manifold. [4]

Fig. 5. 1 Fitting of Nozzle for Intake Manifold.

5.2.2 Using of solenoid valve for flow control technique

A solenoid valve as shown in Fig. 5. 2 is an electromechanical controlled valve. The valve features a solenoid, which is an electric coil with a movable ferromagnetic core in its center. This core is called the plunger. In rest position, the plunger closes off a small orifice. An electric current through the coil creates a magnetic field. The magnetic field exerts a force on the plunger. As a result, the plunger is pulled toward the center of the coil so that the orifice opens. This is the basic principle that is used to open and close solenoid valves. [4]

Fig. 5. 2 Solenoid Valve

5.2.3 Implementation of Gas Kit

As shown in Fig. 5. 3 gas kit comprising LPG gas cylinder, vaporizer, regulator, solenoid valve where successfully installed into the experimental model and operated very well.

Fig. 5. 3 Conversion kit

5.3 Technical Specification

In this project the car used is a BMW- 520i - F10 – 2013 2000 GTI Automatic as shown in Fig. 5. 4, the engine specification for this car are as it follows:-

Fig. 5. 4 BMW- 520i - F10

The engine specification for the BMW- 520i - F10 2000cc it is shown in the Table 5. 1**:**

Table 5. 1 BMW- 520i - F10: the engine specification

Bore*Stroke	86 mm & 85.9 mm
Power	184 hp @ 6000 rpm.
Torque	170 Nm/4100 rpm.
Cooling system	Water cooling
Stroke	4 Stroke
# of cylinder	Four cylinder
Engine displacement	2000 cc
Compression ratio	10.5 : 1

5.4 Dynamometer

Fig. 5. 5 BMW- 520i - F10 on Dynamometer

After install the conversion kit in the vehicle, it should be know what happen to the performance for the vehicle, so can be obtained an indication of power and torque by set a load (in this project set it on 20%) and using a dynamometer as shown in Fig. 5. 5 to measure the power and torque at different speed.

5.5 Gas analyzer (MGT5)

A BMW- 520i - F10 it is modified to run on the duel fuel mode with a little modification, the performance of the engine is measured at different engine speed by a dynamometer, at the same condition it should be evaluated the emission by use MGT5 gas analyzer as shown in FIG. 5. 6 that exist from combustion of the duel fuel.

Fig. 5. 6 Gas analyzer (MGT5)

Chapter 6

Measurement of performance

6.1 Introduction.

6.2 Measurement of Engine Power.

6.3 Measurement of Engine Torque.

6.4 Power and Torque Measurement on Dynamometer.

6.1 Introduction

Engine horsepower is measured by using a dynamometer. The dynamometer places a load on the engine and measures the twisting force the engine crankshaft places against the load. The load is usually a brake preventing the wheels from spinning.

What the dynamometer is really doing, however, is measuring the torque output of the engine. In a vehicle, torque is measured at various engine speeds, or revolutions per minute (RPM). These two numbers are fed into a formula -- torque times RPM divided by 60,000 to arrive at horsepower. The Society of Automotive Engineers has two standards for determining horsepower: net and gross. Gross horsepower removes most loads from the engine, including emission controls, before testing. Net horsepower is what's found by testing the same kind of stock vehicle you'd find at the showroom, and that's the measurement now used in advertising and manufacturer literature.

Horsepower is determined from the torque because torque is easier to measure. Torque is defined specifically as a rotating force that may or may not result in motion. It's measured as the amount of force multiplied by the length of the lever through which it acts. For example, if you use a one-foot-long wrench to apply 10 pounds of force to a bolt head, you're generating 10-pound-feet of torque.

Torque, as mentioned above, can be generated without moving an object. However, when it moves an object, it then becomes "work," and this is what most people think of when they think of torque (usually in terms of towing). The more torque produced by an engine, the more work potential it has.

6.2 Measurement of Engine Power

In physics, power is the work done in time or, with other words, is the rate of doing work. In rotational systems, power P [W] is the product of the torque T [Nm] and angular velocity ω [rad/s].

$$P=T\cdot\omega$$

The standard unit of measurement for power is W (Watt) and for rotational speed is rad/s (radian per second). Most of the vehicle manufacturers are providing the power of the engine in bhp (brake horse power) and the rotational speed in rpm (rotations per minute). Therefore, we are going to use conversion formulas for both rotational speed and power.
To convert from rpm to rad/s, we use:

$$\omega\ \text{[rad/s]}=N\ \text{[rpm]}\cdot\pi 30$$

To convert from rad/s to rpm, we use:

$$N\ \text{[rpm]}=\omega\ \text{[rad/s]}\cdot 30\pi$$

The engine power can also be measured in kW instead of W for a more compact value. To convert from kW to bhp and reverse, we use:

$$P\ \text{[bhp]}P\ \text{[kW]}=1.36\cdot P\ \text{[kW]}=P\ \text{[bhp]}1.36$$

In some cases you might find HP (Horse Power) instead of bhp as unit of measurement for power.

Having rotational speed measured in rpm and torque in Nm, the formula to calculate power is:

$$P\ \text{[kW]}P\ \text{[HP]}=\pi\cdot N\ \text{[rpm]}\cdot T\ \text{[Nm]}30\cdot 1000=1.36\cdot\pi\cdot N\ \text{[rpm]}\cdot T\ \text{[Nm]}30\cdot 1000$$

Example. Calculate the engine power in both kW and HP, if the engine torque is 150 Nm and engine speed is 2800 rpm.

$$PP=\pi\cdot 2800\cdot 15030\cdot 1000=44\ \text{kW}=1.36\cdot\pi\cdot 2800\cdot 15030\cdot 1000=59.8\ \text{HP}$$

6.3 Measurement of Engine Torque

Torque can be regarded as a turning force applied on an object. Torque (vector) is the cross product between a force (vector) and a distance (scalar). The distance, also called the lever arm, is measured between the force and the turning point. Similar to a force, torque is a vector and is defined by an amplitude and a direction of rotation.

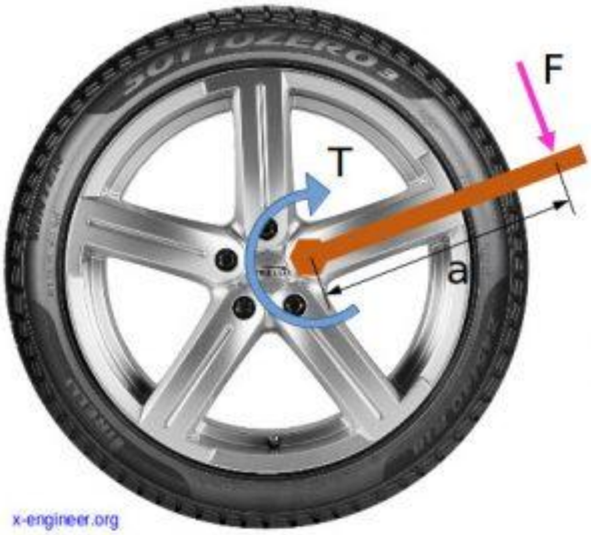


Fig 6.1 Tightening torque at wheel bolt

Imagine that you want to tighten/loosen the bolts of a wheel as shown in Fig 6.1. Pushing or pulling the handle of the wrench connected to a nut or bolt, produces a torque (turning force) that loosens or tightens the nut or bolt.

The torque T [Nm] is the product of the force F [N] and the length of the lever arm a [m].

$$T = F \cdot a$$

In order to increase the magnitude of the torque we can either increase the force, the length of the lever arm or both.

Example: Calculate the torque obtained on the bolt if the arm of the wrench has 0.25 m and the applied force is 100 N(which is approx. equivalent with a pushing force of 10 kg)

$$T = 100 \cdot 0.25 = 25 \text{ Nm}$$

The same torque could be obtained if the lever arm was 1 m and the force only 25 N.
The same principle applies to internal combustion engines. The torque at the crankshaft is produced by the force applied on the conrod journal through the connecting rod.

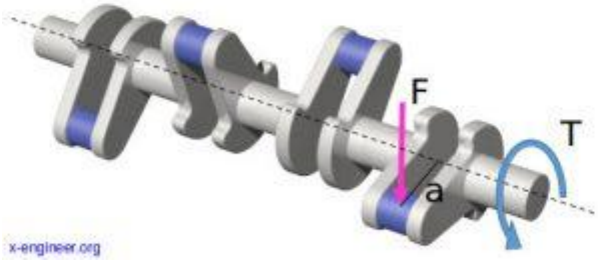


Fig 6.2 Torque at crankshaft

The torque T will be produce at the crankshaft on each conrod journal, every time the piston is in the power stroke. The lever arm a in this case is the crank radius (offset) as shown in Fig 6.2.
The magnitude of the force F depends on the combustion pressure within the cylinder. The higher the pressure in the cylinder, the higher the force on the crankshaft, the higher the output torque as shown in Fig 6.3.

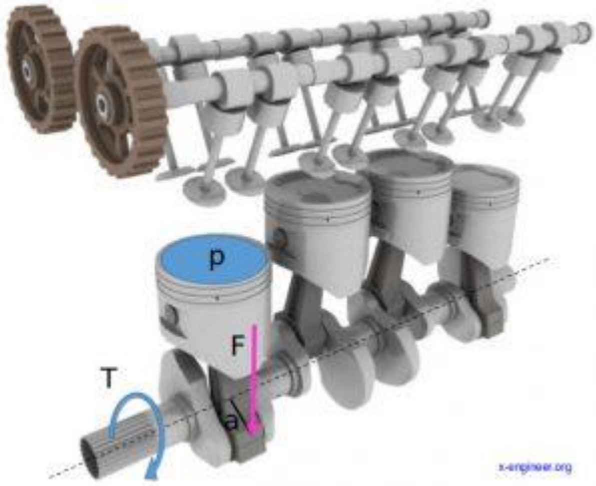


Fig 6.3 Engine torque calculation function of cylinder pressure

The length of the lever arm has impact on the overall engine balance. Increasing it too much can lead to engine imbalance, which results in higher forces in the crankshaft journals.
Example: Calculate the torque at the crankshaft for an engine with the following parameters:

Cylinder bore, B [mm]	85
Cylinder pressure, p [bar]	12
Crank offset, a [mm]	62

First, we calculate the area of the piston (assuming the the piston head is flat and its diameter is equal with the bore of the cylinder):

$$Ap=\pi B24=\pi\cdot 0.08524=0.0056745 \text{ m2}$$

Second, we'll calculate the force applied to the piston. To get the force in N (Newton), we'll use the pressure converted in Pa (Pascal).

$$F=p\cdot Ap=120000\cdot 0.0056745=680.94021 \text{ N}$$

Assuming that all the force in the piston goes into the connecting rod, the torque is calculated as:

$$T=F\cdot a=680.94021\cdot 0.062=42.218293 \text{ Nm}$$

The standard unit of measurement for torque is N·m (Newton meter). Especially in the USA, the unit of measurement for engine torque is lbf·ft (foot-pounds). The conversion between N·m and lbf·ft is:

$$1 \text{ lbf}\cdot\text{ft}1 \text{ N}\cdot\text{m}=1.355818 \text{ N}\cdot\text{m}=0.7375621 \text{ lbf}\cdot\text{ft}$$

For our particular example, the torque in imperial units (USA) is:

$$T=42.218293\cdot 0.7375621=31.138615 \text{ lbf}\cdot\text{ft}$$

6.4 Power and Torque measurement on dynamometer

Power and torque measurement has been acquired on 20% engine load by submitting the engine throw a dynamometer test, and reading the torque and power amounts where observed on different mixing ratios of LPG and Gasoline with respect to engine speed, and the relationship between the power and torque and engine speed where represented in a Cartesian graph.

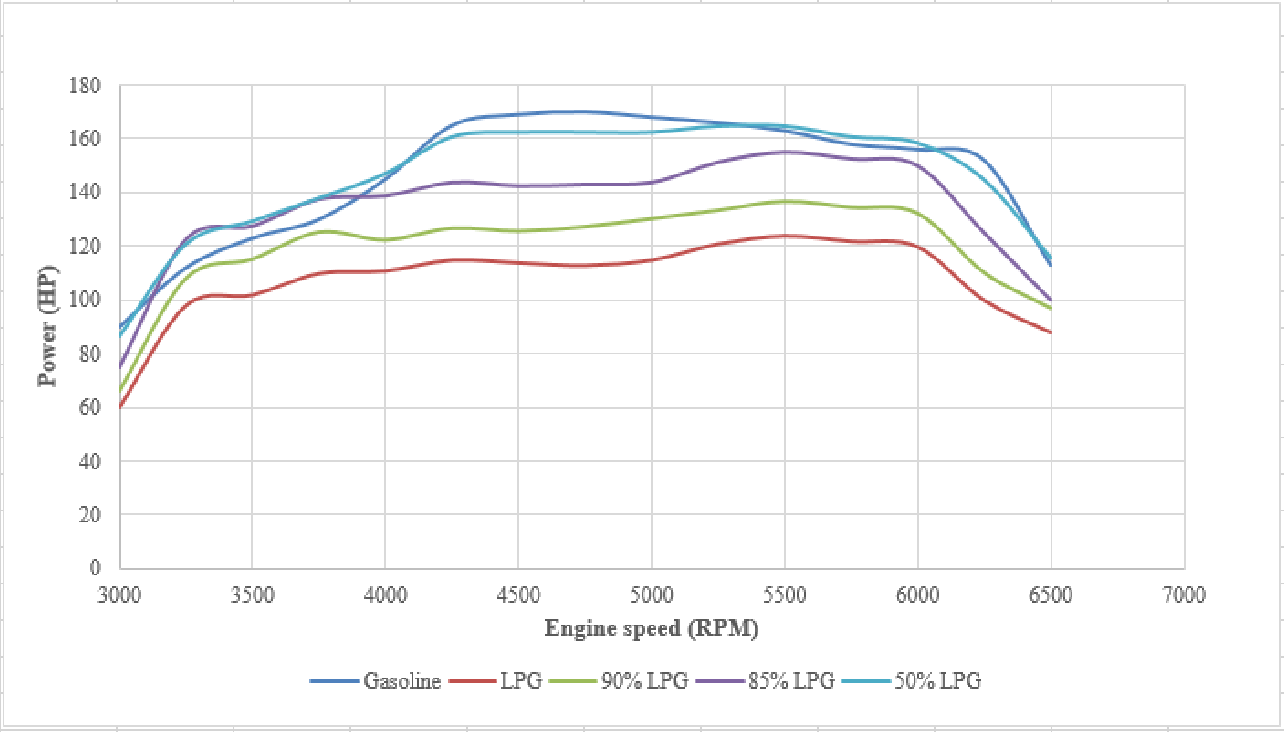


FIG 6. 1 Engine Power Measurement

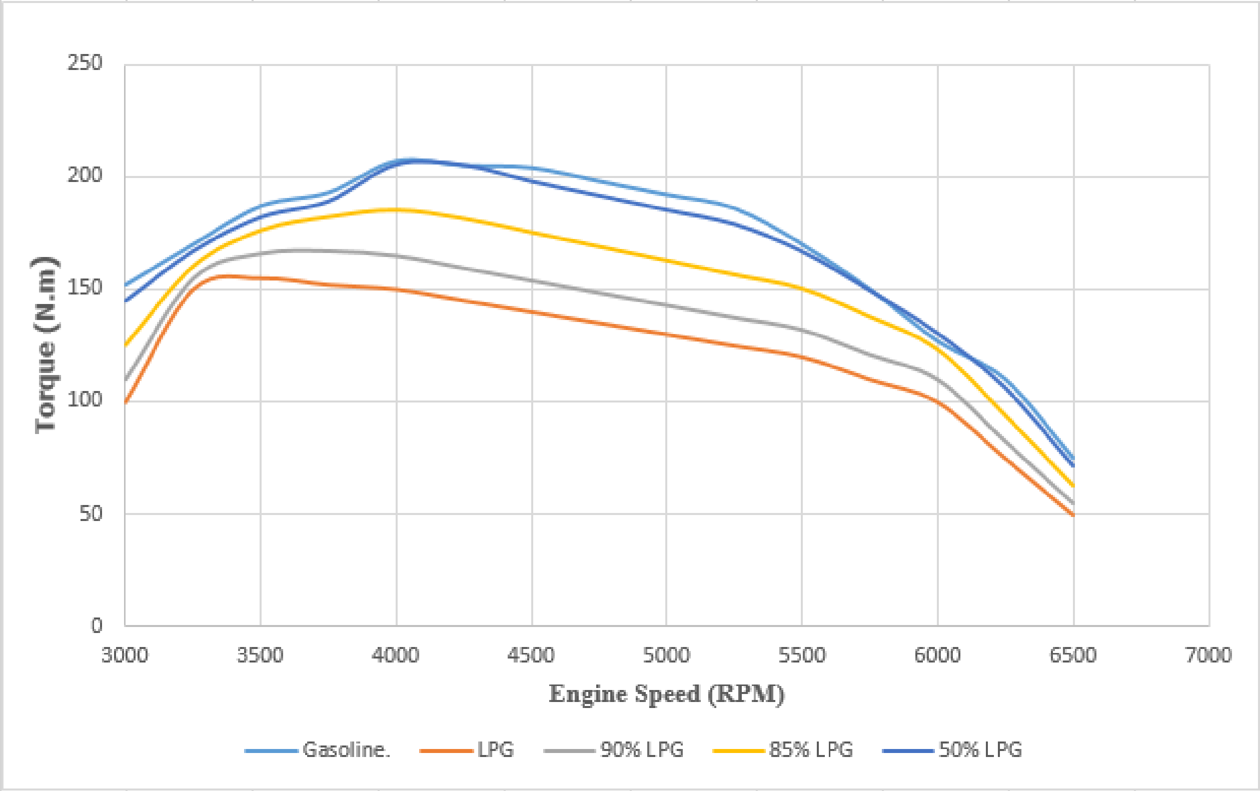


FIG 6. 2 Engine Torque Measurement

Chapter 7

Emission characteristics of an LPG–Gasoline dual fuel engine

7.1 Introduction.

7.2 Emission characteristics.

  7.2.1 Hydrocarbon (HC) Emission.

  7.2.2 Carbone Monoxide (CO) Emission.

  7.2.3 Nitrogen Oxides (NOx) Emission.

7.3 Emission Measurement.

  7.3.1 Hydrocarbon (HC) Emission Measurement.

  7.3.2 Carbone Monoxide (CO) Emission Measurement.

  7.3.3 Nitrogen Oxides (NOx) Emission Measurement.

  7.3.4 Carbon Dioxide (CO2) Emission Measurement.

7.1 Introduction

Internal combustion engine undesirable emissions during the combustion process. In this both SI and LPG engines are equally responsible for the same. The emission exhaust into the surrounding pollute the atmosphere and causes the following problem:

- Global warming.
- Acid rain.
- Smog.
- Oder's.
- Respiratory and other health hazards.

The major causes of these emissions are non-stoichiometric combustion dissociation of nitrogen, and impurities in the fuel and air, the emission of concern are unburnt hydrocarbons (HC), oxides of carbon (COx), nitrogen oxides (NOx) and oxide of.

The power of engine that comes from the combustion chamber, which is where hydrocarbons in fuel meet with air. Ideally all oxygen in the air should be converted all the hydrocarbons in fuel to the water and carbon dioxide. But in reality combustion also produces unburned hydrocarbon, nitrogen oxides, carbon monoxide and water.

Inside an engine, the hydrocarbons in gasoline will not burn unless they are mixed with air. This is where the chemistry of combustion begins. Air is composed of approximately 20.95% of oxygen (O2), 78.09% nitrogen (N2) and other amounts of gasses.

The hydrocarbons in fuel normally react only with the oxygen during the combustion process to form water vapor (H2O) and carbon dioxide (CO2), creating the desirable effect of heat and pressure within the cylinder. Unfortunately under certain engine operating condition the nitrogen also react with the oxygen to form nitrogen oxides (NOx). The air fuel ratio (A/F) react on the efficiency of the combustion.

7.2 Emission characteristics

7.2.1 Hydrocarbon (HC) Emission

Hydrocarbons simply it’s an unburned fuel. When combustion does not take enough time to burn that will give a large amount of hydrocarbons are emitted from the combustion chamber. A normal process called wall quenching occur as the combustion flame front burns to the relatively cool walls of the combustion chamber. This cooling extinguishes the flame before all of the fuel is fully burned, leaving a small amount of hydrocarbon to be pushed out the exhaust valve. Another cause of excessive hydrocarbon emission is related to combustion chamber deposits because these carbon deposits are porous, hydrocarbon is forced into these pores as the A/F mixture is compressed. When combustion takes place, this fuel does not burn however, as the piston begins its exhaust stroke, these hydrocarbons are released into the exhaust stream.

The most common cause of excessive hydrocarbon emission is misfired which occurs due to ignition, of air induction problem. That’s depend on how severe the misfire inadequate spark or a noncombustible mixture (either too rich or too lean) will cause hydrocarbon to varying ranges.

7.2.2 Carbon Monoxides (CO) Emission

Carbon monoxides is a colorless, odorless, poisonous gas formed when carbon in fuels are not burned completely. It is a byproduct of highway vehicle exhaust, which contributes about 60 % of all CO emissions. In cities automobile exhaust can cause as much as 95% of all CO emission. These emission can result in high concentration of CO particularly in local areas with heavy traffic congestion.

Carbon monoxide is a byproduct of incomplete combustion and is essentially partially burned fuel if the A/F mixture does not have enough oxygen present during combustion it will not burn completely.

An oxygen started combustion environmental occurs as a result of A/F which are richer than stoichiometry (14.7: 1). There are several engine operating conditions when this occurs normally.

7.2.3 Nitrogen Oxides (NOx) Emission

Oxides of nitrogen are produced by combustion of all fossil fuels including coal and gas fired power stations and motor vehicles. The two main nitrogen oxides are nitric oxide (NO), or fired nitrogen or nitrogen monoxide and nitrogen dioxide (NO2) the sum of which is equal to NOx. But almost 90% of the NOx combustion product is in the form of NO which is then oxidized to nitrogen dioxide (NO2) in the air.

High pressure and temperature in cylinder which occur during the combustion process can cause nitrogen to react with oxygen to form oxides of nitrogen (NOx). Although there are various forms of nitrogen-based emission comprise oxides of nitrogen (NOx), nitric oxide (NO) makes up the majority, about 98% of all NOx emission produced by the engine.

Generally speaking the largest amount of (NOx) in LPG-Gasoline dual fuel is produce during moderate to heavy load condition when combustion pressures and temperature are their highest.

7.3 Emission measurement.

Emission measurement has been acquired on 20% engine load by submitting the engine throw gas analyzer test, and readings of CO, CO_2, HC and NOx amounts where observed on different mixing ratios of LPG and Gasoline with respect to engine speed, and the relationship between the emission measurements and engine speed where represented in a Cartesian graph.

7.3.1 Hydrocarbon (HC) Emission Measurement

The production of HC emissions is lower in LPG-Gasoline Duel fuel than gasoline, especially on the idling speed and low loads because at low loads the cylinder charge is better mixed which leads to more efficient burning of all hydrocarbons on most mixing ratios, hence LPG remain unburned go to the exhaust, which attributed to the decrease in HC emissions at lower RPM.

The unburned hydrocarbon (HC) emission is created while the engine is running with pure gasoline, pure LPG, 90% LPG, 85% LPG and 50% LPG, that with respect to different rpm selection:

Table 7. 1: The HC Emission with different ratios of LPG in a dual fuel mode:

RPM	Gasoline	LPG	90% LPG	85% LPG	50% LPG
1000	470	305.5	336.05	412.425	423
1500	149	96.85	106.535	130.7475	134.1
2000	125	81.25	89.375	109.6875	112.5
2500	147	95.55	105.105	128.9925	132.3
3000	145	94.25	103.675	127.2375	130.5
3500	142	92.3	101.53	124.605	127.8
4000	140	91	100.1	122.85	126
4500	138	89.7	98.67	121.095	124.2
5000	137	89.05	97.955	120.2175	123.3
5500	136	88.4	97.24	119.34	122.4
6000	134	87.1	95.81	117.585	120.6

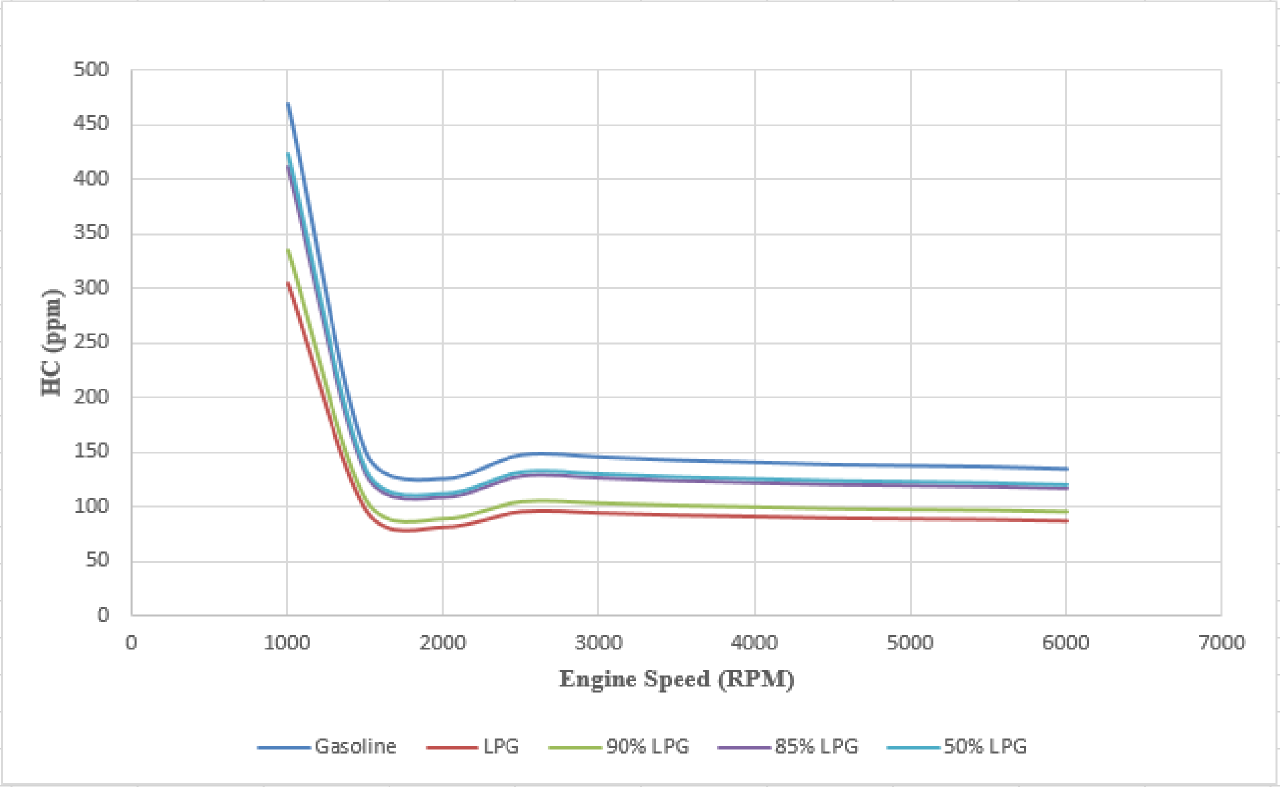


FIG 7. 1 : The HC Emission with Different Ratios of LPG.

Fig.7.1 shows the variations of HC. The production of HC emissions is lower in gasoline + LPG than gasoline, especially on the low RPM because at low RPM the cylinder charge is better mixed which leads to more efficient burning of all hydrocarbons on most mixing ratios, hence LPG remain unburned go to the exhaust, which attributed to the decrease in HC emissions at lower RPM.

7.3.2 Carbone Monoxide (CO) Emission Measurement.

The dual-fuel runs better than gasoline at most operating conditions. This shows that the dual-fuel can achieve better combustion at higher loads compared to gasoline. The CO emission from dual-fuel for all ranges of engine speed has better CO emission especially in the mid-range which holds most of the time the part loads range. CO is usually attributed to a high equivalence ratio and/or poor mixing. With the straight gasoline, as additional fuel is injected. With the dual-fuel engine, this drop in CO does occur, indicating more efficient combustion with the addition of the premixed LPG/air charge, and lowering the requirement for additional gasoline fuel and this is applied for most ratios of mixing. In this table shown the Co emission created while the engine is running with pure gasoline, pure LPG, 90% LPG, 85% LPG and 50% LPG, that with respect to different rpm selection:

Table 7. 2: The CO Emission with different ratios of LPG in a dual fuel mode:

RPM	Gasoline	LPG	90% LPG	85% LPG	50% LPG
1000	7.3	4.599	5.28885	6.20865	6.57
1500	5.7	3.591	4.12965	4.84785	5.13
2000	4.1	2.583	2.97045	3.48705	3.69
2500	2.8	1.764	2.0286	2.3814	2.52
3000	2.3	1.449	1.66635	1.95615	2.07
3500	2	1.26	1.449	1.701	1.8
4000	1.9	1.197	1.37655	1.61595	1.71
4500	1.95	1.2285	1.412775	1.658475	1.755
5000	1.92	1.2096	1.39104	1.63296	1.728
5500	1.88	1.1844	1.36206	1.59894	1.692
6000	1.85	1.1655	1.340325	1.573425	1.665

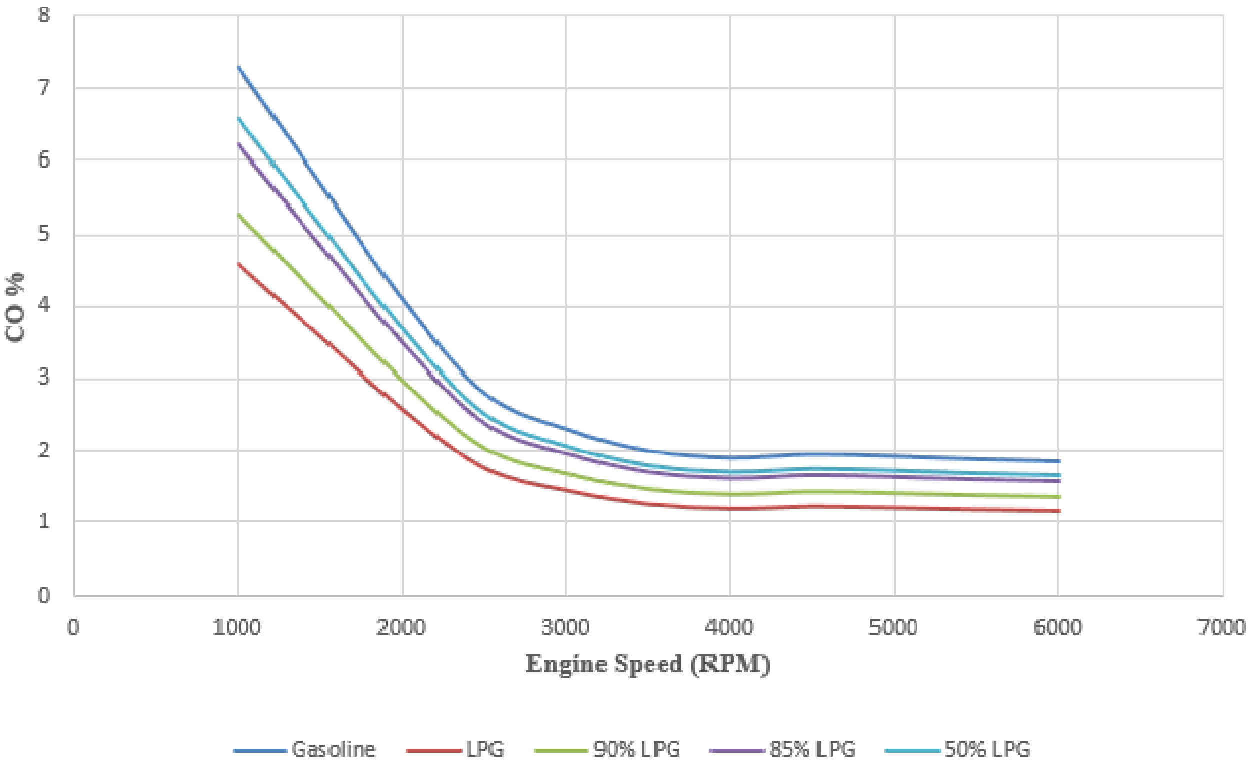


FIG 7. 2: The CO Emission with Different Ratios of LPG

For most operating conditions, the CO for dual-fuel is 59% lower than for Gasoline, as shown in Fig.7.2 Generally, the dual-fuel runs better than gasoline at most operating conditions. This shows that the dual-fuel can achieve better combustion at higher loads compared to gasoline. The CO emission from dual-fuel for all ranges of engine speed has better CO emission especially in the mid-range which holds most of the time the part loads range. CO is usually attributed to a high equivalence ratio and/or poor mixing. With the straight gasoline, as additional fuel is injected. With the dual-fuel engine, this drop in CO does occur, indicating more efficient combustion with the addition of the premixed LPG/air charge, and lowering the requirement for additional gasoline fuel and this is applied for most ratios of mixing.

7.3.3 Nitrogen Oxides (NOx) Emission Measurement.

As shown in figure compares the relationship between NO*x* emission and engine speed for gasoline and dual-fuel during maximum operating conditions. It is clear that the dual-fuel establishes an overall superiority over the gasoline, and the NO*x* concentration in the exhaust gases for dual-fuel, on average, is 54% lower than gasoline. During most range of-speed than with gasoline operation. This is due to the higher air-fuel ratio and higher combustion temperatures. As the speed increases, the gasoline fuel engine is running at a lower air to fuel ratio compared to dual-fuel, which means the reduction of oxygen intake. Therefore, to reduce the NOx emissions for dual-fuel the LPG injection should be increased. Another method is to reduce the airflow, making the mixture richer than that under normal dual-fuel operation. This can be done by throttling the intake air at light loads using the more sophisticated control of an electric control unit (ECU). Another solution is to mix LPG with only part of the incoming airflow. So over all ranges of engine speed the LPG have a clear superiority for most of mixing ratios. In this table shown the exhaust gas emission NOx created while the engine is running with pure gasoline, pure LPG, 90% LPG, 85% LPG and 50% LPG, that with respect to different rpm selection:

Table 7. 3: The NO*x* Emission with different ratios of LPG in a dual fuel mode:

RPM	Gasoline	LPG	90% LPG	85% LPG	50% LPG
1000	22	9.9	10.89	11.385	15.4
1500	95	42.75	47.025	49.1625	66.5
2000	175	78.75	86.625	90.5625	122.5
2500	276	124.2	136.62	142.83	193.2
3000	500	225	247.5	258.75	350
3500	800	360	396	414	560
4000	1150	517.5	569.25	595.125	805
4500	1400	630	693	724.5	980
5000	1650	742.5	816.75	853.875	1155
5500	1850	832.5	915.75	957.375	1295
6000	2100	945	1039.5	1086.75	1470

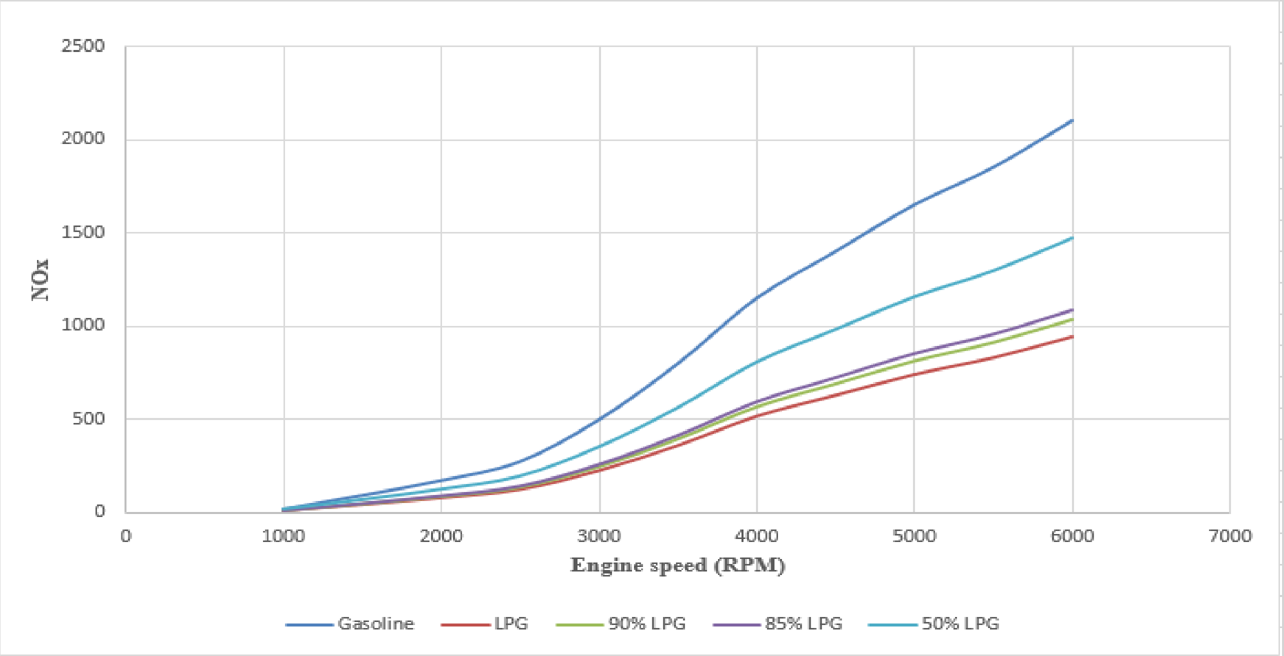


FIG 7. 3: The NOx Emission with Different Ratios of LPG

Fig.7.3 compares the relationship between NOx emission and engine speed for gasoline and dual-fuel during maximum operating conditions. It is clear that the dual-fuel establishes an overall superiority over the gasoline, and the NOx concentration in the exhaust gases for dual-fuel, on average, is 54% lower than gasoline. During most rang of-speed than with gasoline operation. This is due to the higher air-fuel ratio and higher combustion temperatures. As the speed increases, the gasoline fuel engine is running at a lower air to fuel ratio compared to dual-fuel, which means the reduction of oxygen intake. Therefore, to reduce the NOx emissions for dual-fuel the LPG injection should be increased. Another method is to reduce the airflow, making the mixture richer than that under normal dual-fuel operation. This can be done by throttling the intake air at light loads using the more sophisticated control of an electric control unit (ECU). Another solution is to mix LPG with only part of the incoming airflow. So over all ranges of engine speed the LPG have a clear superiority for most of mixing ratios.

7.3.4 Carbon Dioxide (CO2) Emission Measurement.

CO2 concentration in the exhaust gases is mainly a function of the chemical composition of the fuel and its hydrogen to carbon ratio, and the efficient conversion of CO to CO2 via the chemical kinetic reaction path. The hydrogen to carbon ratio for gasoline fuel is 1.87:1 compared to 2.6:1 for LPG. When the theoretical chemical combustion equations at stoichiometric are calculated for the combustion of LPG and $C_{8.26}H_{18.3}$, then it works out that for every litter of gasoline burned, 2392g of CO2 is produced and for every litter of LPG burned, 1665g of CO_2 is produced. This represents a theoretical reduction of 30% (volume basis) for a 100% combustion efficiency at stoichiometric. Test results for most operating conditions in Figure 4 show that the dual-fuel system gave consistently lower CO2 emission at most operating conditions throughout the entire speed range, with greater divergence at higher speeds. At m most operating condition, the dual-fuel gave an average of 31% less CO2 emission than gasoline, as shown in Figure 4. To gasoline. The results obtained in most cases returned better than theoretical reductions. This could be due to low conversion from CO to CO2, but the above results of CO would negate this. Another reason for the extra low reduction in CO2 emissions could be inefficient combustion due to a high equivalence ratio of the straight gasoline system. As shown In this table the CO_2 emission created while the engine is running with pure gasoline, pure LPG, 90% LPG, 85% LPG and 50% LPG, that with respect to different rpm selection:

Table 7. 4: The CO_2 Emission with different ratios of LPG in a dual fuel mode:

RPM	Gasoline	LPG	90% LPG	85% LPG	50% LPG
1000	10.2	5.712	6.2832	7.14	8.67
1500	12.1	6.776	7.4536	8.47	10.285
2000	12.4	6.944	7.6384	8.68	10.54
2500	12.6	7.056	7.7616	8.82	10.71
3000	12.9	7.224	7.9464	9.03	10.965
3500	13	7.28	8.008	9.1	11.05
4000	13.1	7.336	8.0696	9.17	11.135
4500	13.4	7.504	8.2544	9.38	11.39
5000	13.6	7.616	8.3776	9.52	11.56
5500	13.8	7.728	8.5008	9.66	11.73
6000	14.1	7.896	8.6856	9.87	11.985

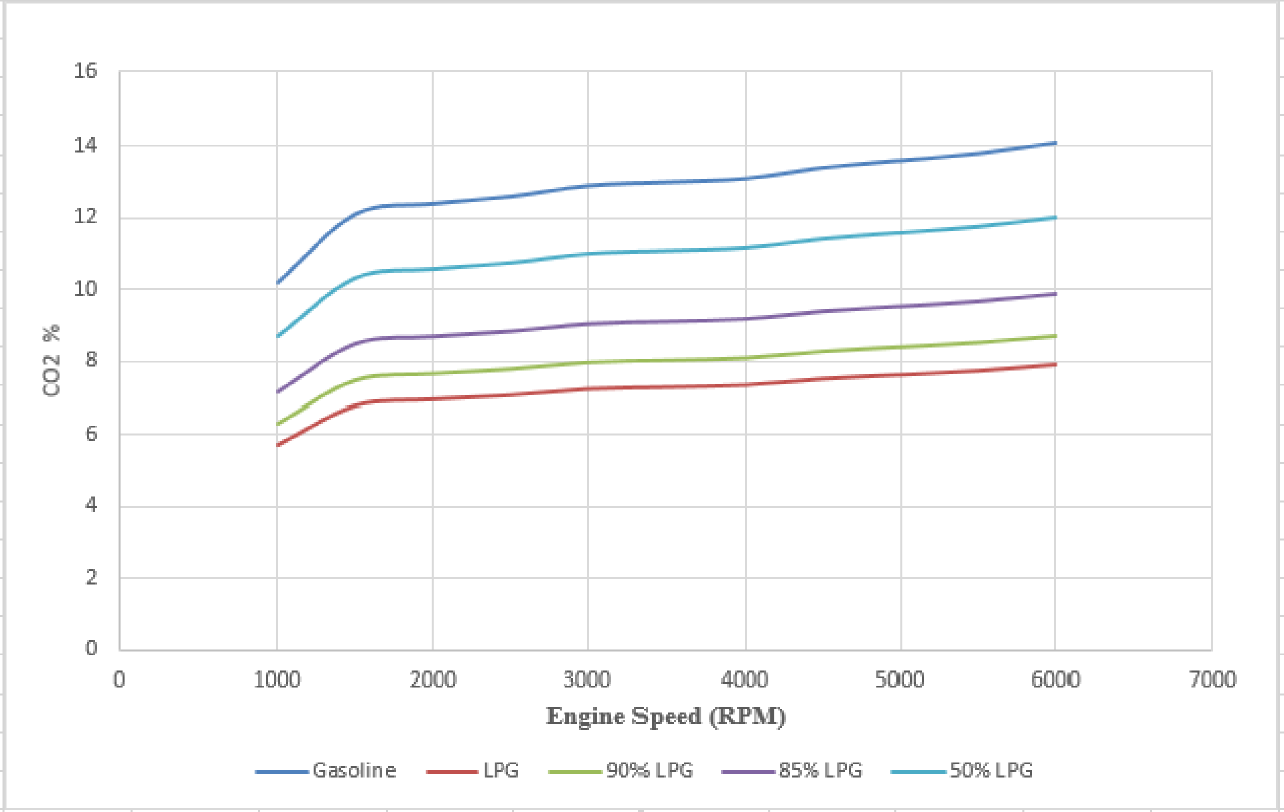


FIG 7. 4: The CO2 Emission with Different Ratios of LPG

CO2 concentration in the exhaust gases is mainly a function of the chemical composition of the fuel and its hydrogen to carbon ratio, and the efficient conversion of CO to CO2 via the chemical kinetic reaction path. The hydrogen to carbon ratio for gasoline fuel is 1.87:1 compared to 2.6:1 for LPG. When the theoretical chemical combustion equations at stoichiometric are calculated for the combustion of LPG and C8.26H18.3, then it works out that for every litter of gasoline burned, 2392g of CO2 is produced and for every litter of LPG burned, 1665g of CO2 is produced. This represents a theoretical reduction of 30% (volume basis) for a 100% combustion efficiency at stoichiometric. Test results for most operating conditions in Fig.7.4 show that the dual-fuel system gave consistently lower CO2 emission at most operating conditions throughout the entire speed range, with greater divergence at higher speeds. At m most operating condition, the dual-fuel gave an average of 31% less CO2 emission than gasoline, as shown in Fig 7.4. to gasoline. The results obtained in most cases returned better than theoretical reductions. This could be due to low conversion from CO to CO2, but the above results of CO would negate this.

Conclusion

The results from this study showed that there is a benefits created by the use of LPG as a second fuel in dual fuel gasoline engines. Because the results shows a positive side when it comes to the emissions, where the results showed that in all cases of using LPG alone or alongside the gasoline with different mixing ratios gives lower emissions of NOx by 55% ,CO by 43% ,CO2 by 30% and HC by 32% , but however on the other hand there is the negative side which is represented by the results of the power and torque, where the results showed that power and torque gets lower in all cases of using LPG even with different mixing ratios as a dual fuel alongside with gasoline.

The power of the engine is decreased by almost 30% on most different mixing ratios of LPG and Gasoline, this is due to the fact that the volumetric efficacy of LPG is less than that of Gasoline and this is due to air and LPG ducting throw the intake manifold, where LPG will equbay the volume inside the cylinder which require increasing the amount of air duct to the cylinder and likewise for the torque.

Recommendation

- Use special spark plugs for LPG-Gasoline dual fuel engine.
- Addition some material to the fuel like Alcohol.
- Apply & test this project on a heavy vehicles.
- Study the effect of the after treatment system like EGR & catalyst on the emission and power.

Appendix

Dynamometer

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THE DYNOCOM ADVANTAGE

Your Safety First!
All of our 5000 series units include standard wheel stabilizer bars to prevent the vehicle from moving off of the rollers.

The Strongest Belts in the World
The belt linkage system is comprised of 4 massive Gates Poly Chain® GT3® belts. These belts are superior to competition rubber belts both for speed and horsepower ratings.

Beautiful and functional
The AWD 5000-FX is comprised of stainless steel construction and heavy duty zinc plated diamond decking.

FRENELSA eddy brake/Plug & Play
Dynocom integrates only the highest quality parts – the 5000 Series utilizes only FRENELSA eddy brakes which are recognized as the world's highest quality. In many of competitor units that use the cheapest available retarders which are only a fraction of the cost of our eddy brakes and are of significantly lower quality. Less expensive eddy brakes also have significantly less load holding capacity. The quality of the eddy brakes will be a reflection of how much trouble-free life your dyno is likely to provide. No Costly wiring necessary (pre-wired from the factory.

5000 Series Lift (Assist/Vertical Tie Down Option
This airbag assisted lift kit helps to lift up the vehicle for easy loading and unloading. The unit consist of two assemblies, one for each wheel. Also integrates with a vertical tie down bar which allows for highest repeatability on each dyno run.

Highest Load
CNC Patented tapered shaft for highest load and speed. A first in the dyno industry.

AWD 5000FX – FEATURES & OPTIONS

The AWD-5000-FX series dyno is the world's most affordable mechanically linked AWD chassis dynamometer system. The AWD-5000FX front portion of the AWD unit is a 2WD 5000 Series unit and the rear is a set of linked rollers with 36"-86" inch track width Gates Poly Chain® GT3®. But don't let its price fool you; the AWD 5000-FX dynamometer is capable of supporting speeds up to 175+ MPH and 2000+ HP. The maximum axle weight is 6,500 lbs and the track width range is 36"-86". The AWD 5000-FX was designed for a variety of different testing scenarios – FWD/RWD Cars, Sport Compacts, Motorcycles and ATV's. It is equipped with a Frenelsa eddy brake and you are able to perform acceleration, step, sweep and steady-state tests. • View in real-time torque/horsepower output, at steady and changing speeds, to instantly evaluate changes you've made to the engine's fuel or timing maps. • Diagnose engine and drivetrain problems. • Troubleshoot drivability issues. • Run track ¼ mile or circle track lap simulations with reaction times that you determine in the software parameters.

The AWD-5000-FX Series dyno incorporates linkage which insures that the front and rear rollers are always spinning at precisely the same road speed. This process eliminates the possibility of activating a vehicle's traction control system and also insures that a vehicle's torque management system is operating under the assumption that the vehicle is not skidding, turning or slipping. The AWD-5000-FX can be operated in AWD Mode while testing two-wheel drive vehicles. This process allows the non-driven axle to be spun by the dynamometer rollers at the same speed as the driven axle, eliminating the speed differential that occurs on two-wheel drive dynamometers.

- With the advanced mechanical design of the AWD 5000 FX and reduction in unnecessary and failure prone components, the AWD 5000 FX is the most advanced and affordable AWD system in the world offering a level of performance, technology, and advanced superior design not found in systems priced at much higher levels.

SPECIFICATIONS

Max Axle Weight	6,500 lbs.
Max Horsepower	2000+hp
Max Speed	175+mph
Vehicle Track Range	16" – 86"
Wheelbase Maximum	86"
Wheelbase Length	96" - 122"
Wheelbase Length	60" - 122"
Wheelbase Length	60" - 140"
Max Steady State Torque*	2,300 ft. lbs. per retarder
Max Dynamic Torque	10,000 ft. lbs. per axle
Electrical Requirements	220/240 VAC @ 25AMPs
Air Requirements	90 PSI @ 4.5 CFM

*$HP_{axle} = TORQUE_{axle} \times RPM / 5252$

MGT 5 Gas Analyser

Description:

1 Low current emissions tester without display (basic unit) for the analysis of HC, CO, CO2, O2 emissions with calculation of Lambda.

2 Automatic switch-off (prevents condensed water from penetrating test chamber).

3 Separate pump for separation of condensed water.

4 Emission testing of CNG, LPG and Otto engines possible.

5 Display of measured values via PC/laptop monitor (option).

6 Options:

  a. Can be expanded to measure NO.
  b. LED-display module (as additional slave monitor).

7 Automatic self-check.

The software used to control mixing ratios:

The overall approach of this project has been represented in an experimental evaluation for the data about engine parameters and characteristics from torque and power to emissions.

For that, purpose a car fitted with the LPG kit (engine modification) has been tested using a dynamometer to measure torque and power and a gas analyzer to measure emissions.

The control of injection of LPG has been applied by using the Mimgas company software to change the amount of LPG by changing the values of injection, which is stored in map inside the ECU.

This map contains programmed amount of LPG injection conditions of operating which the engine goes through.

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