ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
School of Mechanical, Chemical and Materials Engineering

Performance Evaluation of Gasoline Vehicle with Gasoline-Ethanol-Methanol Emulsion as a fuel

A project submitted in partial fulfillment of
the requirements for the award of the degree of
Master of Science

in

Automotive Technology Teachers Education

By

Amanuel Abdeta……....GSR/5326/06

Daniel Densa………….GSR/7598/05

Habtamu Deresso……..GSR/5340/06

Tesfaye Bedada………..GSR/5359/06

Major Advisor: N.Ramesh Babu (Assoc. Prof.)
Co-Advisor: Abinet Gosaye (Msc)

Department of Mechanical and Vehicle Engineering

May, 2015

Adama/Ethiopia

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical, Chemical and Materials Engineering

Department of Mechanical and Vehicle Engineering

Performance Evaluation of Gasoline Vehicle with Gasoline-Ethanol-MethanolEmulsion as a fuel

By

Amanuel Abdeta

Daniel Densa

Habtamu Deresso

Tesfaye Bedada

Approved by board of examiners	Signature	Date
______________________	_____________	_____________
Chairman, Dep't Graduate Committee	Signature	Date
______________________	_____________	_____________
Advisor	Signature	Date
______________________	_____________	_____________
Internal Examiner	Signature	Date
______________________	_____________	_____________
External Examiner	Signature	Date

CANDIDATES' DECLARATION

We hereby declare that this project entitled Performance Evaluation of Gasoline Vehicle with Gasoline-Ethanol-Methanol Emulsion as a fuel in partial fulfillment of the requirement for the award of the degree of Master of Science in Automotive Technology Teacher Education is an authentic record of our own work carried out from March 2015 to May 2015 under the supervision of N.Ramesh Babu Associate professor Department of Mechanical and Vehicle Engineering, Adama Science and Technology University. The matter embodied in this paper has not been submitted for the award of any other degree or diploma. All the relevant sources of information used in this paper have been duly acknowledged.

Amanuel Abdeta	___________________	________________
Daniel Densa	___________________	________________
Habtamu Deresso	___________________	________________
Tesfaye Bedada	___________________	________________
	Signature	Date

This is to certify that the above statement made by the candidates is correct to the best of our knowledge and belief. This project has been submitted for examination with our approval.

N.Ramesh Babu (Asso.Prof)	___________________	________________
Advisor	Signature	Date

ACKNOWLEDGEMENT

At first our thanks go to almighty, which, in his power made everything possible. First and foremost, we would like to express our deep whole hearted gratitude and indebtedness to our adviser Mr Ramesh Babu (Associate Professor) and co adviser Ato Abinet Gosaye (Msc) for their unreserved skillful, knowledgeable guidance and support throughout the whole work of our project. Last but not least we would like to extend our heartfelt thanks to Metehara Sugar Factory's management members, Chemical Engineering department and their laboratory assistants, Adama Science and Technology university's Automotive work shop for their uninterrupted co-operation in fulfillment of project.

TABLE OF CONTENTS

Contents Page

LIST OF TABLES

Table №. **Description** **page**

LIST OF FIGURES

Figure №. **Description** **Page**

LIST OF ACRONYMS, ABBREVIATIONS AND SYMBOLS

ICE	Internal combustion engine
GEM	Gasoline-ethanol-Methanol blend
PVC	Polyvinyl chloride
M85	85% Methanol
IMEP	Indicated mean effective pressure
E10	Ethanol ten percent
SI	Spark ignition
RON	Research octane number
UBHC	Unburned hydrocarbon
EISA	Energy independent and security act
EPA	Energy policy act
TBA	Tertiary Butyl Alcohol
NO_x	Nitrogen oxides
CO_2	Carbon dioxide
AFR	Air fuel ratio
ASTM	American Society for Testing and Materials
EPA	Environmental Protection Agency
GHG	Greenhouse gasses
ETCA	Ethiopian Transport and Communication Authority
CDs	Compact discs
Rvp	Reid vapor pressure
LPG	Liquid petroleum gas

Ibt	Initial boiling point
T10	Distilled temperature at 10 percent evaporated
DI	Drivability index
bsfc	Basic specific fuel consumption
Pb	Brake power
Tb	Brake torque
SI	Spark ignition
MON	Motor octane number
RON	Research octane number
API	American petroleum institute
BTDC	Before top dead-center
Tw	Torque at rear wheel
g.r	Gearbox gear ratio
a.r	Back axle ratio
ɳt	Overall transmission efficiency
N	The engine speed in rpm
rpm	Revolution per mint
Pw	Power at wheel
Sfc	Specific fuel consumption
MOE	Ministry of education
WOT	Wide open throttle
IBT	Initial boiling temperature

ABSTRACT

The purpose of this study is to experimentally investigate the engine performance and pollutant emission of a commercial SI engine using ethanol–methanol and gasoline blended fuels with various blends (E10%, M2% and G88% respectively). Removing the biomass limit is one of the great challenges to further enlarge the share of renewable ethanol as alternative for fossil fuels. One of the possible solutions for this constraint is the ternary GEM (Gasoline-Ethanol-Methanol) blends. Our project studies are going to find a suitable alternate fuel, to reduce the exhaust emission level. If the methanol is produced out of renewable sources, these blends can help extend the part of clean fuels on the market. The development of a Tri-Fuel vehicle, capable of operating on any combination of gasoline, ethanol, and methanol, using a single fuel system is described, demonstrating that compatible, affordable transport can be developed, supplied by sustainable organic fuels. The results were compared to performance of engine from use of regular gasoline. The vehicle was tested for brake power, brake torque and brake specific fuel consumption using chassis dynamometer. The performance tests were conducted using chassis dynamo meter on a vehicle equipped with a four cylinder production spark ignition (SI) engine, without any major modifications of hardware to investigate the comparative performance characteristics of the gasoline, ethanol-gasoline and methanol-ethanol-gasoline mixtures. There is a better brake torque performance at the range of 25-30 km/hr when compared to gasoline. At medium speeds there is a reduction in torque compared to gasoline, but it is similar with gasoline-ethanol blend. The brake power of methanol-ethanol-gasoline is higher than gasoline & ethanol-gasoline when the vehicle is driving at medium speed especially at 45 - 50 km/hr at 3rd gear. The brake specific fuel consumption (bsfc) result shows that the performance of the gasoline-ethanol-methanol blend is better than gasoline & gasoline-ethanol blend.

Key words: Ternary blends, brake power, brake torque, brake specific fuel consumption

CHAPTER ONE

1. INTRODUCTION

1.1. Back ground of the study

It is well-known that fossil fuels are being consumed worldwide in enormous amounts and that the demand for energy keeps increasing every year at high rates. The transportation sector is one of the big consumers and during the last decades people have become aware that we cannot depend on these fossil fuels forever because of the shrinking reserves, negative climate change and bad air quality. Hydrogen and electrification are widely cited as possible solutions these days. Electrification and hydrogen are widely investigated and electric cars are already in use. Nevertheless, the low volumetric energy density of batteries and hydrogen provide these vehicles with a limited range, compared to conventional ICE vehicles.

A transition to either hydrogen vehicles or battery electric vehicles will result in increases in both vehicle and infrastructure costs making it questionable if they will become competitive with vehicles running on liquid fuels in the near future. Driven by the Renewable Energy Directive and The Energy Independence and Security, biofuels are likely to be used at increasingly high concentrations over the next years due to the compatibility with modern vehicles and the distribution and fueling infrastructure. For now, bio-ethanol has the lion's share when it comes to non-petroleum-derived transportation energy. Currently, the largest part of the bio-ethanol is used in low level blends but it can also be used in high level blends likeE85 in gasoline flex-fuel vehicles. There are already millions of flex-fuel vehicles on the market but few of these vehicles regularly use E85. Nevertheless, they represent a potentially large market for alcohol fuels. Despite of the projected growth, bio-ethanol is not considered to be viable in the long term as a substitute for fossil fuels, due to the biomass limit. This biomass limit is different for each country, and depends on the amount of biomass that can be grown there, the amount of energy required by the country, any impact of land-use change that may arise and limits set by any impact on the food chain[1,9].

Compared to ethanol, methanol is actually more versatile from a production point of view. Methanol can be produced from a wide variety of renewable sources from gasification of wood, agricultural by-products, municipal waste and alternative fossil fuel based feed stocks (e.g. coal and natural gas). A number of workers have even proposed a sustainable closed-carbon cycle where methanol is synthesized from hydrogen, produced from renewable electricity, and atmospheric CO_2, thus forming a liquid hydrogen carrier and making it an 'electro fuel'. Methanol has been successfully used in large-scale fleet trials[9] and studied on engine test benches. Because of the high octane index, high heat of vaporization and low combustion temperatures, the power and efficiency is significantly higher form ethanol and ethanol compared to gasoline.

Internationally, ethanol has a long history of use as a petrol extender, octane improver and alternative fuel. Ethanol can be made from both renewable biomass and non-renewable petrochemical sources. Renewable fuel grade ethanol is predominantly made from wheat starch and wheat grain. Other feed stocks include the by-products of sugarcane and sorghum processing. Several automobile manufacturers have developed flexible fuel vehicles that can run on neat petrol or fuel that contains 85 per cent ethanol by volume, or any blend of ethanol and petrol from 0 per cent to 85 per cent ethanol.

The corrosive effect of a fuel rises with increasing ethanol content. Materials that normally would not be affected by low percentage ethanol blends have been found to dissolve in the presence of higher ethanol concentrations, including aluminum, brass, zinc and lead. Non-metallic materials that degrade when in contact with high concentrations of fuel ethanol include natural rubber, polyurethane, cork gasket material, leather, polyvinyl chloride (PVC), polyamides, methyl-methacrylates plastics, and certain thermo and thermo set plastics. The swelling and embrittlement of rubber fuel lines and o-rings can, in time, lead to component failure [8].

As global concerns grow regarding energy security, air quality, and climate change, opportunities emerge for alternative fuels to displace the petroleum fuels on which today's transportation sector depends. One such alternative fuel is renewable methanol, a liquid fuel that has been demonstrated to be a successful replacement for gasoline and diesel. This white paper focuses on the options, benefits, and considerations for renewable methanol primarily as a transportation fuel. As a transportation fuel, methanol offers several key advantages. It is a higher octane fuel than gasoline [1]. If spilled or leaked, methanol is biodegradable and less ecologically damaging than conventional fuels [2].Depending on how the methanol is produced, its price at the pump may offer significant fuel cost savings for the end user compared to gasoline and diesel. As an alternative fuel, methanol offers increased energy security from the volatility of the worldwide petroleum market.

However, as with any transportation fuel, the use of methanol entails tradeoffs. It has roughly half of the energy content of gasoline on a volume basis [3]. Like ethanol, methanol is miscible in water and corrosive, requiring materials compatibility and distribution considerations different from gasoline and diesel. Methanol may not be able to fully replace conventional fuels in existing vehicles. However, low level blends of methanol in gasoline are already being used in various parts of the world in today's vehicles, and high level blends, including M85 and M100, are being used in vehicles designed to operate on methanol.

1.2.Statement of the problem

The major problem which worried us is a greenhouse effect. The main contributor to the greenhouse effect is the transport sector due to the heavy and increasing traffic levels. Using pure gasoline fuel as engine fuel is increasing the amount of CO_2, HC & Oxides of nitrogen emissions (NO_x) emission in the atmosphere. The other thing is the cost of gasoline fuel is on an increment trend and consequently affecting the cost of transport especially for those who daily use transport. Because, gasoline fuel is imported from outside, the country is spending lot of foreign exchange.

1.3. Objectives

1.3.1 General Objective

The general objective of this project is to test the performance of the gasoline engine by modifying fuel system with methanol- ethanol and gasoline emulsion as fuel.

1.3.2 Specific objectives:

- Modifying the fuel system of gasoline vehicle.
- Conducting test by gasoline fuel.
- Conducting test on gasoline vehicle with ethanol and gasoline blend.

- Conducting test on gasoline vehicle with ethanol, gasoline and methanol emulsion.
- Comparing the test results.

1.4 Significance of the Project

The project will indicate how and why the alternative fuel is used instead of using pure gasoline fuel and may increase the interest of car manufacturer and vehicle owners to modify their car's fuel system. After the accomplishment and implementation of the modification, the system will have the following basic significance:-

- Reduce the net emissions of greenhouse gases.
- Minimise the need for foreign-produced oil.
- Limit amount of high-octane additives.
- Ethanol reduces the country's dependence on imported oil, lowering the trade deficit, and ensuring a dependable source of fuel.
- Farmers see an increased demand for grain which helps to stabilize prices.
- The quality of the environment improves. Carbon monoxide emissions are reduced, and lead and other carcinogens (cancer causing agents) are removed from gasoline.

Ethanol blends reduce carbon monoxide better than any reformulated gasoline blend more than 25%. Ethanol is low in reactivity and high in oxygen content, making it an effective tool in reducing ozone pollution. Ethanol is a safe replacement for toxic octane enhancers in gasoline such as benzene, toluene, and xylene; because it is produced from renewable agricultural feed stocks, ethanol reduces greenhouse gas emissions.

1.5. Limitations

The scarcity in project facility found at the automotive technology work shop of Adama Science and Technology University had negatively affected the project. The fact that the equipment and instrument found in the work shop are not up to date pose a question as to their accuracy. There were also challenges assorted with the difficulty of finding appropriate manuals for the instruments and devices used for the project. Unavailability of fuel flow measuring device for gasoline, ethanol and methanol blend fuel consumption and air mass consumed was one of the challenges. The exhaust gas analyzer that was available in automotive work shop are damaged and not properly functional, therefore it was not possible to measure exhaust gas emission products.

1.6 Delimitation/Scope of the study

The result of this project was mainly focused on anhydrous ethanol 10%, Methanol 2% and gasoline 88% proportions which is blended to yield mixtures whose long term stabilities are assured and test was conducted on a four stroke four cylinder water cooled spark ignition engine with minor modification of fuel system without much modifications of the hardware by testing with chassis dynamometer.

CHAPTER TWO

2. LITERATURE REVIEW

Alcohols are suitable substitutes as alternate fuels for use in SI engines, as they have properties compatible to gasoline fuels, that too their octane rating is more than 100. If alcohols are blended in small quantities with gasoline, no engine modification is necessary. Engine modification and change in fuel composition are two methods to improve the performance of the engine and reducing pollution levels. Farayedhi et al. investigated the efficiency of CE with oxygenated fuels of ethanol and methanol used as blends of 10, 15, and 20 % by volume with gasoline and it was reported that these blends improved brake thermal efficiency. The leaded fuel performed better than the oxygenated blends in terms of the maximum output of the engine except in the case of 20 % by vol. methanol and 15 % by vol. ethanol blends. Overall, the methanol blends performed better than the other oxygenated blends in terms of engine output and thermal efficiency. Ceviz et al. [6] reported the effects of ethanol-unleaded gasoline blends on cyclic variability in an SI engine. The results showed that the coefficient of variation in indicated mean effective pressure (IMEP), CO and UBHC emissions decreases by using ethanol-unleaded gasoline blends as a fuel, while CO2 concentration increased with 10 % ethanol by volume fuel blend.

Bahattin conducted experiments on SI engines with blends of E25 (75% gasoline and 25% ethanol by vol.), E50, E75 and E100 fuels at a constant load and speed. The experimental results show that the most suitable fuel in terms of performance and emissions was E50. Then, the compression ratio was raised from 6:1 to 10:1. The engine was tested with E0 fuel at a compression ratio of 6:1 and with E50 fuel at a compression ratio of 10:1 at full load and various speeds without any knock[11]. The cylinder pressures were recorded for each compression ratio and fuel. The experimental results showed that engine power increased by about 29% when running with E50 fuel compared to the running with E0 fuel. Also, the specific fuel consumption and CO are reduced. Al-Baghdadi carried out investigations on blends of ethanol with gasoline 30% by volume and reported that these blends increased engine power, thermal efficiency and reduces the nitrogen oxides, CO and HC emissions. The alcohol used to change/modify the attitude toward the present fuel, i.e., gasoline and Search for new alternatives. In this study, the first approach was selected with the aim of improving the combustion characteristics of gasoline, which will be reflected in improving the engine performance and that is done by mixing methanol, ethanol and gasoline fuel. Together with carefully formulated base fuel composition they contribute to efficiency and long life. They are chemicals, which are added in small quantities either to enhance fuel performance or to correct a deficiency. They can have surprisingly large effects even when added in little amount [2].

In this paper we studied the effect of ethanol –gasoline blend, and mixture of ethanol- methanol –gasoline blend, also compare between them. By considering the environmental and the financial or economical consideration, an attempt has been made to increase the performance of the engine by dealing with the alcohol additives. The engine performance analysis measured, running the engine at varying load and constant speed. Hopeful results were obtained and the work carried out is presented.

2.1 Types of Alcohol Fuel

There are several different types of alcohol. Each type is derived by a slightly different method or from a different raw material. We are interested in the two types' methanol and ethanol. Methanol may be familiar as the fuel used in Indy-type race cars. Methanol is one possible source for fuel for car, although it yields less energy than ethanol.Ethanol is the best choice to run car. It is formed by the fermentation of sugars from a number of types of organic materials. Wheat, corn, rice, beets and cane are examples of materials with high sugar content. They give a high yield when fermented and distilled. All types of liquors contain ethyl alcohol also known as grain alcohol [13].

Two types of ethanol are employed as fuel in:

- ❖ Anhydrous ethanol low water content max 0.4% by volume and it is obtained from the regular ethanol by water elimination. This product is to be blended with gasoline 20 to 25%. Anhydrous ethanol (ethanol with less than 1% water) can be blended with gasoline in varying quantities up to pure ethanol (E100), and most spark-ignited gasoline style engines will operate well with mixtures of 10% ethanol (E10).

- Regular ethanol wet up to 4-9% water by volume. Produced by direct distillation. Used as pure fuel in ethanol or Flex-fuel engines.

Methanol is the simplest alcohol which can be made from

- Various biomass resources like wood, as well as from coal.
- Natural gas, however, today nearly all methanol is made from natural gases because it is cheaper and it is a light, volatile, colorless, flammable, toxic liquid with a distinctive odor that is somewhat milder and sweeter than ethanol.

Methanol is produced naturally in the anaerobic metabolism of many varieties of bacteria, and is ubiquitous in the environment. As a result, there is a small fraction of methanol vapors in the atmosphere. Methanol is safer in case of accidental fire than gasoline, because it burns cooler. One problem is that the flame from a methanol fire is difficult to see in bright sunlight.

2.2 The promise of alcohol fuels:

Alcohols have been popular alternative fuels for many years. In fact, Henry Ford's first car was fuelled with alcohol. Both ethanol and methanol are now used as transportation fuels and will likely play an increasingly important role in the future[26].

Alcohol fuels are safer and less polluting than petroleum fuels .They are relatively benign if spilled in the environment. Alcohol fires are extinguished with water. Well-designed alcohol produces no harmful emissions and is powerful generators of carbon credits. Alcohol fuels are produced locally, from wasted or underutilized products, such as molasses, or even flare gas. Ethanol is the least toxic of liquid or gaseous fuels. Methanol’s toxicity can be managed. Both alcohols are denatured with a bitter agent, color and odor. Today, ethanol is produced for less than half to cost of kerosene and methanol for less than half the cost of ethanol.

2.3 Advantages of ethanol/Methanol

- Provide a viable alternative to reduce the greenhouse effect.
- Produced domestically.

- Easily mixed with gasoline.
- Be used (and already is on a wide scale) as an oxygenated in gasoline.
- Create new jobs in the country related to its production [10].
- Reduces NOx concentrations.
- Lower the emissions, higher performance, and lower risk of flammability than gasoline.
- Methanol can be manufactured from a variety of carbon based feedstock such as natural gas, coal, and biomass (e.g., wood) and the use of methanol would help reduce U.S. dependence on imported petroleum. On the down side, methanol produces a high amount of formaldehyde in emissions.
- Methanol can easily be made into hydrogen.
- Methanol may potentially be used to create hydrogen for hydrogen fuel cell vehicles in the future.

2.4. Blending GEM & Storage

- The test fuel has to be blended by skilled person with a very good understanding of the test and the difficulties associated with it.
- Particularly close attention has to be paid in obtaining a uniform start temperature and making sure that the fuel is not exposed to temperatures that might cause early vaporization. Therefore blending is to be performed in an area conditioned to a maximum of 0^0C. For the same reason, the fuel is to be stored in the conditioned area until just before the test [2].

2.4.1 Gasoline-Ethanol Blend

The approximate ethanol content of a gasoline ethanol blend can be tested by the "Water Extraction Test". This procedure is as follows. Determination of Alcohol Content in Blends-Water Extraction Method Place 100ml. of the gasoline/ethanol blend in 100 ml. glass stopper graduated cylinder. Since they were actions taken by state legislatures, they did not affect federal requirements for oxygenate usage[1,17]. The bans had the effect of causing ethanol usage as a fuel oxygenates to increase in the U.S. The oxygen mandate for reformulated gasoline was removed by the Energy Policy Act of 2005. The act also required usage of renewable fuels, causing another increase in ethanol usage. The Energy Independence and Security Act (EISA) of

2007 increased the mandated amounts of biofuels for 2008through 2012 and extended the period of required use of biofuels to 2022. The EISA also required targeted amounts of advanced and cellulosic biofuels for the periods 2009 to 2022 and 2010 to 2022, respectively (Figure 2.1).

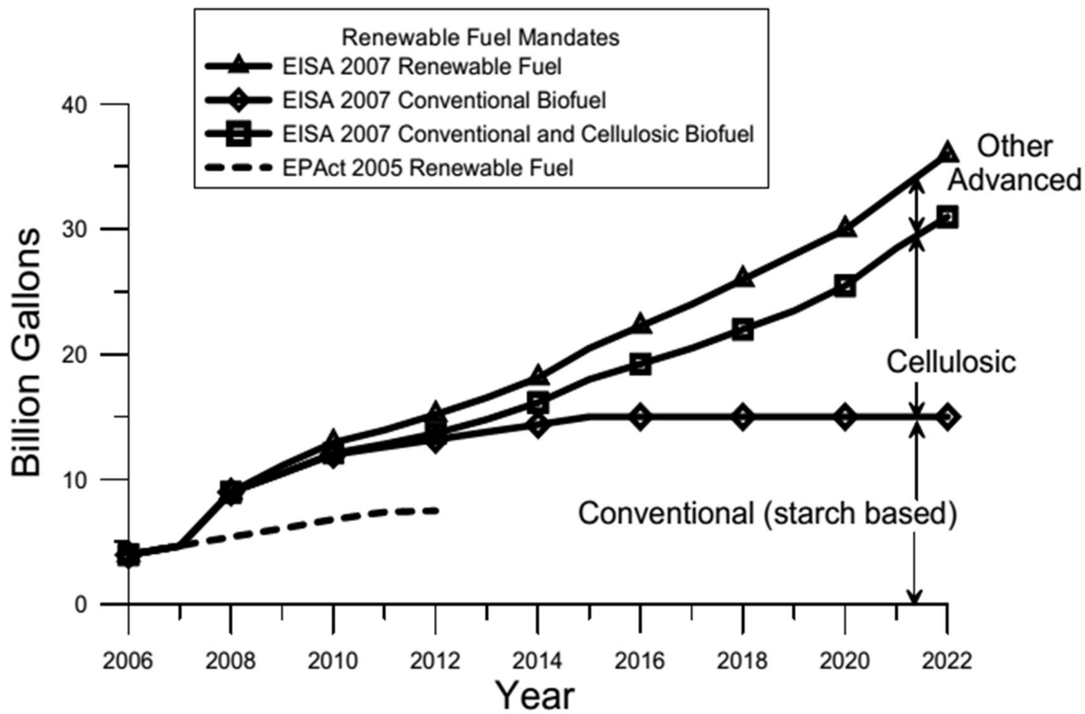


Figure 2.1 Renewable and biofuel mandates from the Energy Policy Act (EPA) of 2005 and the Energy Independence and Security Act (EISA) of 2007.

2.4.2 Gasoline-Methanol Blends

The use of methanol has been suggested as a means of extending nation's Supply of liquid fuels. The transportation sector of the economy is one of the largest users of liquid fuels today, and several investigations have been made of the possibility of blending portions of methanol with gasoline to extend the supply of that fuel reduce emissions[15].

2.4.3 Methanol Tolerance

That the ethanol produced in the fermentation of glucose by yeast eventually reaches a concentration at which it prevents further conversion of substrate is a well-known fact. In a systematic study of a number of yeasts has shown that this inhibitory concentration, while varying widely among different yeasts, is characteristic enough for a given species or strain that definite "alcohol (ethanol) tolerance" values may be assigned. An empirical relationship between these alcohol tolerance values and the amounts of reserve materials formed, especially fats, has been described.

Results of a preliminary attempt to acquire information concerning the mechanism of this ethanol inhibition indicated that the alcohol may exert its effect on glucose utilization in a culture by limiting the size of the active cell population. Since limitation of multiplication is a rather general effect, it is important to know whether the phenomenon of alcohol tolerance hinges around specific properties of ethanol alone or whether related substances may not produce similar effects. In the present work this question has been investigated by ascertaining the effects of added methanol upon the utilization of glucose by three yeasts.

2.5. Storage

Bulk storage of methanol should be done in appropriately designed horizontal or vertical storage tanks. To limit moisture infiltration, a conservation vent with a flame arrestor is recommended, or nitrogen blanketing. Proper grounding is essential, given methanol's low conductivity. For storage at retail service stations, the underground tank is preferred. Underground storage has several advantages: the fuel stays at a relatively constant cool temperature; the aboveground space is maximized for vehicle refueling; and refilling from tanker trucks can be done using gravity rather than a pump. Tanks for methanol can be made from stainless steel, carbon steel, or methanol-compatible fiberglass[26].

Lining the excavation area surrounding the tank with natural or synthetic liners that cannot be penetrated by methanol for underground methanol tanks at service stations, conservation vents with flame arrestors are typical to prevent water absorption rather than nitrogen blanketing. This is especially important when storing neat methanol since the vapor space in the tank will be flammable, unlike storage of gasoline or M85 where the vapor space will be too rich to be flammable. Existing underground petroleum tanks must be thoroughly cleaned before storing methanol to remove all water and sediment. Some underground storage tanks use liners which must be methanol-compatible. In addition to moisture infiltration from the air, water often gets into underground storage tanks from inadequate seals on the refilling manholes. Efforts should be made to prevent water infiltration from the surface above since this water often includes impurities such as sodium and chloride ions that greatly increase the corrosiveness of methanol.

2.6 Fuel Quality

The quality of fuel used in any motor vehicle engine is very important to its long life and proper operation. If the fuel is not right for the air temperature or if fuel changes to a vapor incorrectly, drivability will suffer. Gasoline is a complex mixture of approximately 300 various ingredients, mainly hydrocarbons, refined from crude petroleum oil for use as fuel in engines. Refiners must meet gasoline standards set by the American Society for Testing and Materials (ASTM), the Environmental Protection Agency (EPA), state regulatory agencies and their own company standards [9].

2.6.1 Effects of fuel quality

Blends of gasoline ,ethanol and methanol, so far as possible the best results were obtained for each given proportion, from all gasoline to as much alcohols as gasoline, but no change in the thermal efficiency or rate of consumption of gasoline could be made; this result showing that the effect of the alcohols, if any, has balanced. Since higher compressions could be used, depending on the proportion of alcohol, a similar set of experiments was made with one of the alcohol engines in which the compression pressure was about 130 pounds per square inch. Again the thermal efficiency could not be increased or the consumption rate decreased to values better than the best obtained for gasoline alone in a gasoline engine. For the two engines tests were required to determine the best possible results for each percentage used; but the results are not conclusive, for there is a question whether the particular engine used for the latter tests, with the higher degree of compression, was free from conditions of construction that affected the best results obtainable, to avoid such problem, the test is must conduct on the same engine [8,9].

Use of E10 (10% ethanol and 90% gasoline by volume) achieves [5]:

- 6% reduction in petroleum use,
- 1% reduction in GHG emissions, and
- 3% reduction in fossil energy use.

Use of E85 (85% ethanol and 15% gasoline by volume) achieves:

- 73–75% reduction in petroleum use,
- 14–19% reduction in GHG emissions, and

- o 34–35% reduction in fossil energy use.

Use of E95 (95% ethanol and 5% gasoline by volume) achieves:

- 85–88% reduction in petroleum use,
- 19–25% reduction in GHG emissions, and
- 42–44% reduction in fossil energy use.

2.7 Gasoline fuel

Gasoline or petrol is a transparent, petroleum-derived liquid that is used primarily as a fuel in internal combustion engines. It consists mostly of organic compounds obtained by the fractional distillation of petroleum, enhanced with a variety of additives. Some gasoline also contains ethanol as an alternative fuel. Under normal ambient conditions, its material state is liquid, unlike liquefied petroleum gas or natural gas [9].

2.7.1Gasoline Additives

Gasoline fuels consists mostly of organic compounds obtained by the fractional distillation of petroleum, enhanced with a variety of additives to improve the performance of the fuel such as preventing fuel line freezing; minimizing friction etc as shown in table 2.1 below.

Table.2.1. Gasoline additives and its purposes [17]

Additive	Purpose
Detergents/deposit control additives	To eliminate or remove fuel system deposits
Anti-ices	To prevent fuel-line freeze up
Fluidizer oils	Used with deposit control additives to control intake valve deposits
Corrosion inhibitors	To minimize fuel system corrosion
Anti-oxidants	To minimize gum formation of stored gasoline
Metal deactivators	To minimize the effect of metal-based components that may occur in gasoline.
Lead replacement additives	To minimize exhaust valve seat recession
Methanol	To increase the octane number of fuel and to minimize

2.8. Characteristics of ethanol-blended fuels

Blending ethanol with gasoline has multiple effects. Ethanol increases the heat output of the unleaded gasoline, which produces more complete combustion resulting in slightly lower emissions from unburned hydrocarbons. The higher the concentrations of ethanol, the more the fuel has polar solvent-type characteristics with corresponding effects on conducting fire suppression operations. However, even at high concentrations of ethanol, minimal amounts of water will draw the ethanol out of the blend away from the gasoline. Ethanol and gasoline are very similar in specific gravity. The two differing fuels mix readily with minimal agitation, but the blend is more of a suspension than a true solution.

Note that property values may vary slightly depending on ethanol blend levels and the composition and density of the base gasoline to which ethanol is added as shown in table 2.2 below.

Table 2.2 Gasoline and Fuel Grade Ethanol

	Gasoline	**Fuel Ethanol**
Flash Point	*-45°F*	*-5°F*
Ignition Temperature	*530–853°F*	*793°F*
Specific Gravity	*0.72–0.76*	*0.79*
Vapor Density	*3–4*	*1.49*
Vapor Pressure	*38–300 mmHg*	*44 mmHg*
Boiling Point	*100–400°F*	*173°F*
Flammable Range (LEL–UEL)	*1.4%–7.6%*	*3.3%–19%*
Conductivity	*None*	*Yes*
Smoke Character	*Black*	*Slight to none*
Toxicity		*Lower than gasoline*
Water Solubility	*None*	*Completely*
Reference: *The National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards*		

2.9 Physical-chemical properties of methanol and ethanol

Table 2.3 shows the properties of gasoline, ethanol and methanol. Ethanol is reported as having an octane rating of 129 RON and 102MON, with a combined octane rating of 115 ((R+M)/2). Methanol reported as having an octane rating of 133 RON and 105 MON, with a combined octane rating of 119((R+M)/2). In contrast the combined octane rating of regular gasoline is 87 and that of premium gasoline is 93.A simplified cooling effect has been estimated in Table2.3. T in Table2.3 refers to the change in temperature of a stoichiometric mixture when the alcohol evaporates, assuming constant air properties. It is an indication of the evaporative cooling property of the fuel, as opposed to an absolute number, which depends on initial temperature, evaporation rate, time of injection, compression heating during evaporation, and other complications in the real system. In a stoichiometric mixture, ethanol has an evaporative cooling of about 4 times that of gasoline, while methanol has the effect of about 9 times larger than gasoline. These numbers are large, and projection of the effect of the evaporative cooling of ethanol on allowed turbo-charging and compression ratio have been presented elsewhere[26].

Table 2.3 Properties of the alcohol fuels and gasoline

Fuel type	Units	Gasoline	Ethanol	Methanol	Methanol with co solvent 50% Methanol
Chemical formula			CH_3CH_2OH	CH_3OH	/TBA
RON			129	133	114
MON			102	105	96
(R+M)/2			115	119	105
Specific gravity	Kg/l	0.75	0.794	0.796	0.789
Net heat of combustion(LHV)	MJ/l	32	21	16	21
Net heat of combustion(LHV)	MJ/Kg	43	27	20	27
Latent heat of vaporization	BTU/gal	800	2600	3300	2500
Latent heat of vaporization	MJ/kg	0.3	0.91	1.16	0.88
Vaporization energy/heat of combustion		0.007	0.034	0.058	0.033
Stoic air/fuel ratio		14.6	9	6.4	8.8
Equiv. Latent heat of vaporization	MJ/kg air	0.02	0.10	0.18	0.10
ΔT Air	K	-28	-138	-246	-137

2.10 Octane Number

Pure methanol has a very high blending octane value (BOV). This number reflects the fact that the blending of methanol with gasoline is a very effective method of increasing the octane number of the fuel. The effect is less pronounced in newer automobiles. The elimination of knocking has been demonstrated as the result of this effect. Higher compression ratios may be utilized and the attendant increases in fuel economy realized. The effective increase in octane number depends upon the octane number of the base gasoline used in the blend. Methanol is more effective in raising the octane number of an originally lower octane number fuel.

2.10.1 Effective Octane model

The octane rating of a fuel is a measure of ability of the unburnt end gases to resist Knock, that is, spontaneous ignition of the fuel, under the specified test conditions. Ideally, a fuel should resist ignition before arrival of the flame-front in the piston. The octane rating of the fuel is dependent on its composition. There are specific engine conditions to determine the octane rating of a fuel. Two numbers have been used historically, the Research Octane Number (RON) and the Motoring Octane Number(MON).Refer tables 2.4 and 2.5 for details.

Table 2.4 Engine conditions for Research Octane (RON)

Test engine conditions	**Research Octane**
Test method	ASTM D2699-92 105
Engine	Cooperative fuels research
Engine RPM	600 rpm
Intake air temperature	Varies with barometric pressure (eg 88KPa=19.4C,101.6KPa=52.2C)
Intake air humidity	3.56-7.12g H_2O/Kg dry air
Intake mixture temperature	Not specified
Coolant temperature	100 C
Oil temperature	57 C
Ignition advance-fixed	13 degrees BTDC
Carburetor venture	Set according to engine altitude(eg 0-500m=14.3mm,500-1000m=15.1mm)

The conditions of the Motor Octane Number method represent severe, sustained high speed, high load driving. For most hydrocarbon fuels, including those with either lead or oxygenates, the Motor Octane Number will be lower than the Research Octane Number.

Table 2.5 Engine conditions for Motor Octane (MON)

Test engine conditions	**Motor Octane**
Test method	ASTM D2700-92 104
Engine	Cooperative fuels research
Engine RPM	900 rpm
Intake air temperature	38 C
Intake air humidity	3.56-7.12g H_2O/Kg dry air
Intake mixture temperature	149
Coolant temperature	100 C
Oil temperature	57 C
Ignition advance-fixed	Varies with compression ratio(eg 14-26 degrees BTDC)
Carburetor venture	14.3mm

In this paper, the effective octane of the alcohols is determined using a computational model for the engine and the air/fuel chemistry. The knocking model is a modification of the model that has been described before [Bromberg]. The model uses pressures and temperatures from the literature on the characteristics of a Cooperative Fuels Research(CFR) engine, used to determine octane properties of the fuel.

2.11 Effect of fuel volatility on vehicle performance

A fuel's ability to vaporize or change from liquid to vapor is referred to as its volatility. Volatility is an extremely important characteristic of gasoline which affects many vehicle performance parameters. Figure 2.2 lists the effects of gasoline volatility on vehicle performance. The effects of volatility on vehicle performance are also shown graphically in Figure 2.2.For example, if the volatility curve in Figure 2.2 moves down in the initial range of up to 30%evaporated, then more fuel would vaporize at lower temperatures and it may cause poor hot starting and vapor lock problems. The effects of shifting the volatility curve in the mid and higher percent evaporated ranges are also clearly marked on Figure 2.2.

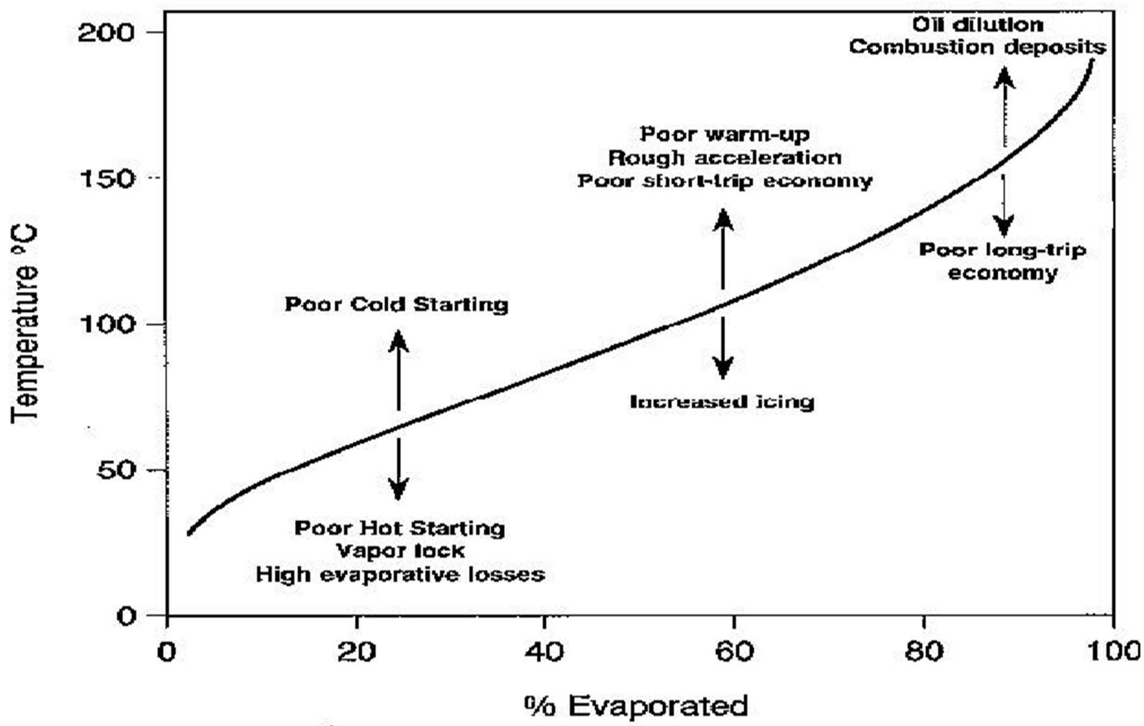


Figure 2.2 The effect of volatility on vehicle performance

Vapor Pressure: ASTM D4814 specifies a vapor pressure by state (or in some cases, portions of a state) for each month of the year. During the regulatory control period of June 1st to September 15th (at retail) volatility restrictions apply. These restrictions require that fuels sold during the control period have a vapor pressure no greater than 9.0 psi or 7.8 psi depending upon the area. During this control period, gasoline/ethanol blends containing 9-10v% ethanol are allowed to be up to 1.0 psi higher in vapor pressure. Exclusive of this control period, there are currently no federal restrictions on the vapor pressure of gasoline/ethanol blends except for reformulated gasoline.

During the portion of the year when no federal volatility restrictions apply to gasoline, it is still recommended that the vapor pressure increase for gasoline/ethanol blends be no more than 1.0 psi higher than the all-hydrocarbon base fuel. Unless other more volatile blending components are being used, as shown figure 2.3 the addition of ethanol should not create a vapor pressure increase above 1.0 psi in conventional gasoline, and in fact the increase is often below 1.0 psi [18].

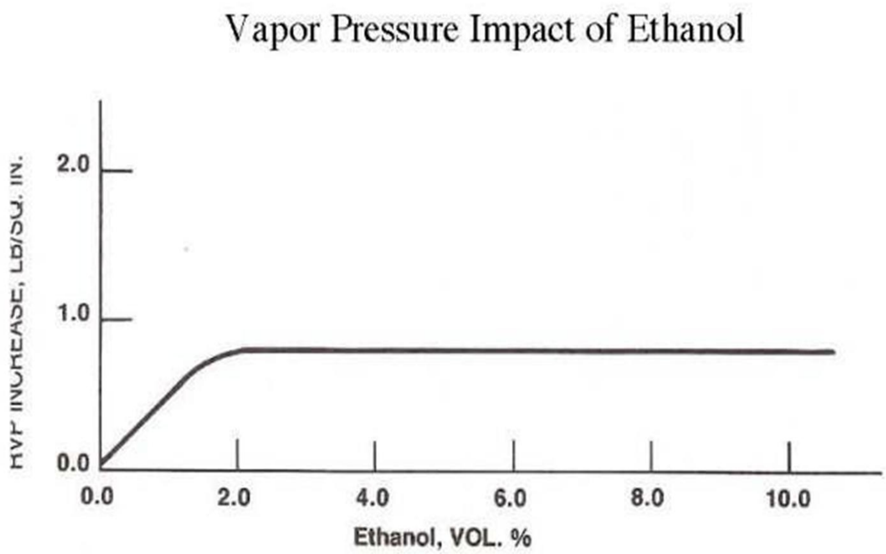


Figure 2.3 Vapor pressure impact of ethanol

The vapor pressure of a fuel is a measure of its "front end" volatility. Fuels with excessively high vapor pressure may contribute to hot drive ability/hot restart problems such as vapor lock. Fuels of too low a volatility may contribute to poor cold starts (long cranking time) and poor warm up performance due to too little vapor being formed [18].

Distillation Properties: ASTM D4814 also provides guidance on distillation characteristics & a maximum temperature at which 10v%, 90v%, and 100v% (T10, T90, and end point) of a gasoline sample should evaporate. The specification also provides a temperature range at which 50% (T50) of the sample should evaporate. This range provides a minimum of 150°F - 170°F and a maximum of 230°-250°F depending on the volatility class. Ethanol will depress the T50 point of the gasoline to which it is added. As an example, adding 10v% ethanol to a gasoline with a T50 of 210°F can result in a blend with a T50 of 180°-185°F.

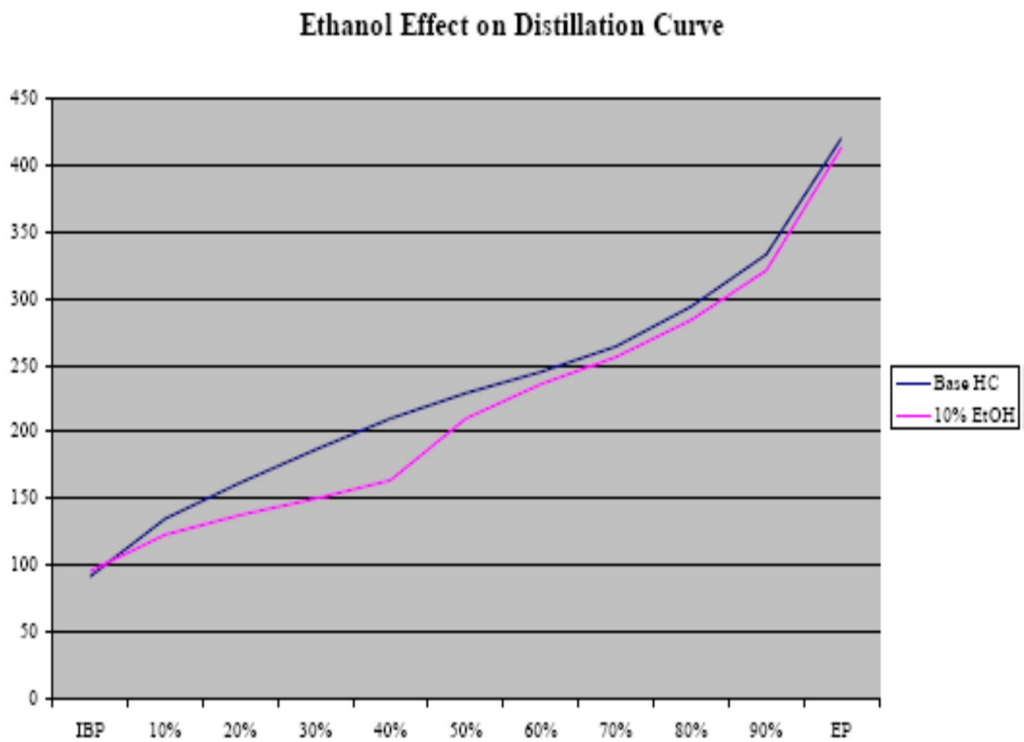


Figure2.4 Ethanol effect on distillation curve

The T50 would be about the same for E15 but tests have shown that E15 would also lower the T60 and T70 more than E10 [18].

Drive ability Index: ASTM D4814 also includes specifications for Drive ability Index (DI). The DI is based on the relationship between fuel distillation temperatures and vehicle cold start and warm up drive ability performance. The DI is indicated by the following formula:

DI= drive-ability index

T10 = distillation temperature at 10% evaporated

T50 = distillation temperature at 50% evaporated

T90 = distillation temperature at 90% evaporated

v% = volume percent ethanol

DI = (1.5 x T10) + (3.0 x T50) + T90 + (2.4ºF x v% ethanol)

Drivers have an expectation of how a vehicle will operate under normal driving conditions. How well a vehicle conforms to this expectation can be defined as drivability. When assessing drive ability and the use of ethanol, the following factors are often considered: (1)hot operation; (2) cold-start; (3) enleanment; (4) materials compatibility; and (5) onboard diagnostics.

2.12 Ethanol temperature correction factors

Fuel grade ethanol is typically sold on a net gallon basis, i.e., temperature corrected to 60°F. This is also standard procedure for most petroleum products. However, fuel grade ethanol has a different coefficient of expansion than petroleum products and requires different conversion tables than gasoline. The coefficient of expansion for fuel grade ethanol is 0.00063/F°. This corresponds approximately to API temperature correction table 6B (General Products) for API Gravity 51.5°. The following table provides the temperature correction factors to convert a fuel grade ethanol volume to 60°F. Gross gallons can be adjusted to net gallons at 60°F with the preceding table. For instance, if 8,000 gross gallons with a temperature of 76°F were converted to net gallons, this would equate to 7,919.2 net gallons as follows:

8,000(gross gallons) x 0.9899(factor) = 7919.2(net gallons)

Tables may vary slightly among ethanol producers. This is because of potential small differences in gravity as well as the possible rounding of the coefficient of expansion (e.g., 0.0006 instead of 0.00063). The applicable ethanol supplier should be consulted to obtain copies of their temperature correction table refer table 2.6 and to determine if they differ from the previous table [18].

Table: 2.6 Fuel ethanol correction of volume to $60^{O}F$

Fuel Ethanol
Table for Correction of Volume to 60°F

Temp °F	Factor	Temp °F	Factor	Temp °F	Factor
-10	1.0441	28	1.0202	66	0.9962
-9	1.0435	29	1.0195	67	0.9956
-8	1.0428	30	1.0189	68	0.9950
-7	1.0422	31	1.0183	69	0.9943
-6	1.0416	32	1.0176	70	0.9937
-5	1.0409	33	1.0170	71	0.9931
-4	1.0403	34	1.0164	72	0.9924
-3	1.0397	35	1.0157	73	0.9918
-2	1.0391	36	1.0151	74	0.9912
-1	1.0384	37	1.0145	75	0.9905
0	1.0378	38	1.0139	76	0.9899
1	1.0372	39	1.0132	77	0.9893
2	1.0365	40	1.0126	78	0.9987
3	1.0359	41	1.0120	79	0.9980
4	1.0353	42	1.0113	80	0.9874
5	1.0346	43	1.0107	81	0.9868
6	1.0340	44	1.0101	82	0.9861
7	1.0334	45	1.0094	83	0.9855
8	1.0328	46	1.0088	84	0.9849
9	1.0321	47	1.0082	85	0.9843
10	1.0315	48	1.0076	86	0.9836
11	1.0309	49	1.0069	87	0.9830
12	1.0302	50	1.0063	88	0.9824
13	1.0296	51	1.0057	89	0.9817
14	1.0290	52	1.0050	90	0.9811
15	1.0283	53	1.0044	91	0.9805
16	1.0277	54	1.0038	92	0.9798
17	1.0271	55	1.0031	93	0.9792
18	1.0265	56	1.0025	94	0.9786
19	1.0258	57	1.0019	95	0.9779
20	1.0252	58	1.0013	96	0.9773
21	1.0246	59	1.0006	97	0.9767
22	1.0239	60	1.0000	98	0.9761
23	1.0233	61	0.9994	99	0.9754
24	1.0227	62	0.9987	100	0.9748
25	1.0221	63	0.9981	101	0.9742
26	1.0214	64	0.9975		
27	1.0208	65	0.9968		

Fuel Consumption

The energy content of methanol is less than that of gasoline (8540 Btu/lbvs. 19,080 Btu/lb) so that higher fuel consumption would be theoretically predicted for blends of methanol and gasoline than for straight gasoline. However, these blends will burn more satisfactorily at sub-stoichiometric fuel to air ratios than will gasoline, and this fact together with their better anti-knock qualities and cooler, more efficient engine operation may offset this theoretical prediction. Depending upon the automobile engine tested, fuel economy has been shown to be improved slightly or slightly decreased by the addition of methanol to form blended fuels. Since the blend contains less Btu per gallon, there is a slight but significant increase in efficiency of operation on a mile per Btu basis. This increase is generally reported, and may be of importance economically depending upon the comparative prices of gasoline and methanol on dollars per million Btu bases[20].

Alcohol effects on distillation, cold starting, and vapor lock

Adding alcohols to gasoline depresses the boiling temperature of individually hydrocarbons. The lower alcohols cause significant reduction in the front end distillation temperatures, thus affecting primarily the first 50% evaporated. Lower molecular weight alcohols have the greatest effect on boiling point depression. Methanol causes the largest changes; its effects can be observed even when accompanied by a co-solvent. Higher molecular weight alcohols, such as tertiary butyl alcohol (TBA), propane, butanol, and pentanol, exert smaller changes on the distillation characteristics.

2.13. Effect of ethanol/gasoline blends on emissions

Exhaust emissions from motor vehicles are very sensitive to changes in the air-fuel ratio as shown in Figure 2.5. The data indicate that air-fuel ratios slightly leaner than stoichiometric produce maximum emissions of oxides of nitrogen (NOx) and minimum emissions of hydrocarbons (HC). The response curve for carbon monoxide (CO) remains at a minimum value for mixtures leaner than stoichiometric. Thus ethanol/gasoline blends can be expected to reduce CO, and to a lesser extent HC emissions, due to mixture enleanment in open-loop vehicles calibrated to operate richer than stoichiometric on gasoline. This benefit of lower CO and HC, however, could be offset by increase in NOx. However, at part throttle, low load conditions, there sponse curve for NOx is not as pronounced as illustrated in Figure 2.5, and the NOx emissions under these conditions may not be greatly affected due to enleanment by blends[22].

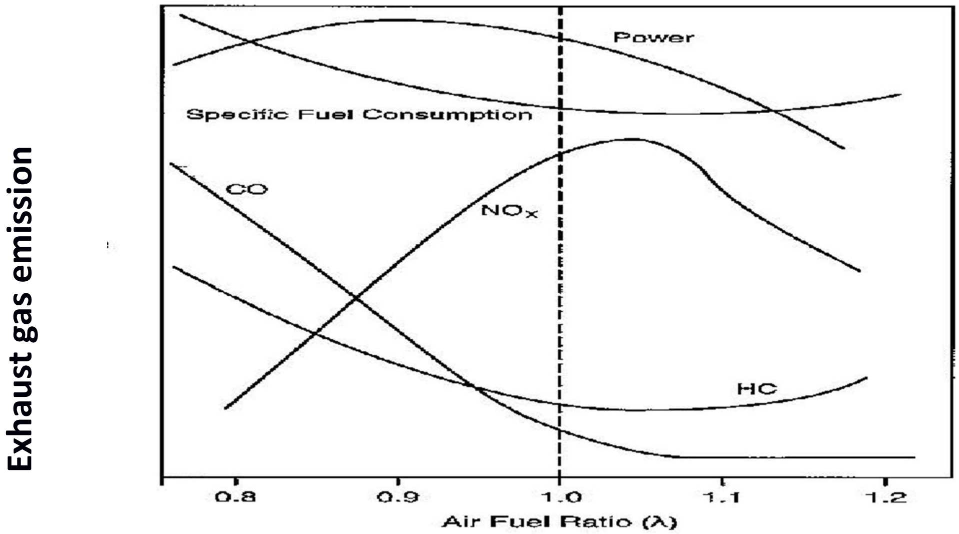


Figure 2.5 Effect of Air-Fuel Ratio on Exhaust Emissions

2.14 Engine performance characteristics

The results of the brake power, torque, and specific fuel consumption for ethanol and methanol gasoline blended fuels at different engine speeds are presented here. When the ethanol content in the blended fuel was increased, the engine brake power slightly increased for all engine speeds. However, the brake power of gasoline was slightly lower than that of E10–E30, especially for low engine speeds (e.g., 1000 rpm). With an increase in ethanol percentage, the density of the blend and the engine volumetric efficiency increased and this caused an increase in power. A similar behavior has been reported by almost all investigators on various types of engines and conditions.

The increase of ethanol content increased slightly the torque of the engine. The brake torque of gasoline was lower than those of E10–E30, especially for low engine speeds. Due to the addition of ethanol the octane number raised. Therefore, antiknock behavior improved and allowed a more advanced timing that result in higher combustion pressure and thus higher torque (Agarwal, 2007). From the experimental results, the brake specific fuel consumption (BSFC) was calculated in order to understand the variations of fuel consumption in the test engine using different ethanol gasoline blended fuels. The BSFC (g/kWh) is defined as the ratio of the rate of fuel consumption (g/h) and the brake power (kW). Also, a slight difference exists between the BSFC using pure gasoline and using ethanol gasoline blended fuels. As engine speed increases reaching1600 rpm, the BSFC decreases reaching its minimum value. This is due to the increase in brake thermal efficiency.

With an increasing fraction of methanol engine power slightly decreased for all engine speeds. The brake power of gasoline was higher than those of M10–M30, especially for high engine speeds (e.g., 2500 rpm). The increase of methanol content decreased slightly the torque of the engine. The brake torque of gasoline was higher than those of M10–M30. Also, a slight difference exists between the BSFC while using a gasoline and while using methanol gasoline blended fuels. As engine speed increased reaching 1600 rpm, the BSFC decreased reaching its minimum value. However, if the spark ignition time is advanced by 2º without any further optimizations, under WOT full load operation conditions, the engine power shows almost no reduction and BSFC can be decreased as well[8].

2.15 Blend properties

Each fuel has its own set of combustion-related properties. These properties change the engine performance and emission characteristics. Laboratory tests were then carried out using ASTM tests standards to determine the combustion-related properties. A list of fuel properties that compares ethanol and methanol gasoline blended fuels is given in Table 1. It shows heat of combustion, Reid vapor pressure (RVP), research octane number (RON), density at 15.5 ºC and distillation temperature including initial boiling temperature (IBT), 10%, 50%, 90% distillation temperatures and final distillation temperature. Ethanol (ethyl alcohol) C_2H_5OH is a clear, colorless liquid with a characteristic, agreeable odor. Ethanol is an alcohol, a group of chemical compounds whose molecules contain a hydroxyl group, –OH, bonded to a carbon atom. Ethanol melts at –114.1 °C, boils at 78.5 °C, and has a density of 0.789 g/mL at 20°C. The heating value of ethanol is lower than that of gasoline. Table 1 further indicates that the heating value of the blended fuel will decrease with the increase of the ethanol content.RON increases with the increase of ethanol concentration. Compared to unleaded gasoline, RON of the blended fuels is increased by 3.5, 8.6 and 14.1, respectively. Therefore, ethanol is an excellent additive for preventing engine knock and improving engine performance where high octane requirements exist. Despite the improved octane performance of ethanol/gasoline blends, engine drive ability is generally degraded.

Cold starting is more difficult because of the added heat of vaporization in blends. Hot starting is complicated because of increased volatility, which leads to potential vapor locking conditions. Adding 10vol%, 20vol% and 30vol.% ethanol to gasoline increase the RVP of the base gasoline of about 24.53 kPa, 19.61 kPa and 18.31 kPa, respectively. The increase in vapor pressure for low level blends of ethanol is caused by dilution of hydrogen bonding between ethanol molecules in the final blend. When ethanol is diluted in gasoline, the hydrogen bonding effect is reduced and the ethanol molecules behave more like their low molecular weight would indicate, resulting in increased volatility. Adding ethanol also modifies the distillation curve of the gasoline.

Methanol CH_3OH, which is also called methyl alcohol, is colorless, odorless, water-soluble liquid. It freezes at -97.8 ºC, and boils at 64.6 ºC. It is miscible with water in all proportions, and spillages are rapidly dispersed. Blends with between 6.7 % and 36 % of air are flammable. The auto-ignition temperature of methanol is 467 ºC, which is high compared with 222 ºC for gasoline. This may account for the high octane number, 106, of methanol; a typical gasoline has an octane number of 90 to100. The heating value of methanol is less than that of gasoline and ethanol so that its blends contain less MJ/kg. Methanol gasoline blends cause slight but significant decrease in efficiency of the engine. Methanol has also a high RON, which increases with the increase of methanol concentration. Compared to unleaded gasoline, RON of the methanol blended fuels is increased by 3.4, 9.6 and 13.6, respectively. This number reflects the fact that the blending of methanol with gasoline is a very effective method of increasing the octane number of the fuel [26].

Moreover, the result of this effect demonstrates the elimination of knocking. It’s possibility of replacing anti-knock additives in gasoline with a low percentage of methanol in a blend, helping to minimize air pollution. Adding 10vol %, 20vol % and 30vol % methanol to gasoline increases the RVP of the base gasoline at about 22.43 kPa, 31.58 kPa and 33.74 kPa, respectively. Because of the disruption of hydrogen bonding in methanol when it is blended with a hydrocarbon, the vapor pressure of a blend of methanol and gasoline deviates greatly from ideal behavior, exhibiting a much higher vapor pressure than would be expected. This excess vapor pressure can lead to vapor problems (drive ability problems), difficulties with hot starts, stalling, hesitation, and poor acceleration. Several solutions to these problems have been proposed. It is possible to add high vapor pressure liquids or gases such as butane either generally or preferably during cold start situations.

Table 2.7. Properties of different ethanol and methanol gasoline blend

Property item	Test fuel							Test method
	Gasoline	E10	E20	E30	M10	M20	M30	
Heat of combustion (MJ/kg)	44.133	42.447	40.672	38.673	41.615	38.233	36.247	ASTM D340
Reid vapour pressure (kPa)	35.00	59.53	54.61	53.31	57.43	66.58	68.74	ASTM D323
Research octane number	84.8	88.3	93.4	98.9	88.2	94.4	98.4	ASTM D2699
Density at 15.5°C (kg/l)	0.7678	0.7760	0.7782	0.7794	0.7692	0.7707	0.7734	ASTM D1298
Distillation temperature (°C)								
IBT	38.5	39.5	40.3	40.7	43.2	43.7	44.5	ASTM D86
10 vol.%	57.2	52.3	55.4	55.7	48.2	50.4	51.3	
50 vol.%	93.5	71.8	71.6	72.5	81.0	79.7	81.6	
90 vol.%	156.0	143.7	143.1	142.7	165.1	164.8	164.7	
End point	181.7	176.1	176.6	176.5	206.2	206.3	206.7	

2.16 The Carburetor

The basic function of a carburetor on a spark ignition engine is to mix the fuel with the incoming air in the proper proportions so that the engine can then burn it efficiently. Most carburetors also control the speed of the engine. They do this by throttling the amount of air the engine receives. Contrast this with a typical diesel engine that has its speed controlled by the amount of fuel injected into it, as it has no air throttle. At test, we need to identify some of the basic elements of a carburetor as this helps explain how they work. You need a minimum of three elements including a source of fuel, usually from a fuel bowl, a venture that we'll talk about in a moment,

and a fuel-metering device called a jet. If we want to use the carburetor to control the engine's speed, we'll also need some form of throttleto vary the amount of airflow going into the engine.
Taking it one piece at a time, the fuel bowl does a couple of things. As stated, it provides a source of fuel. But it does it in a very specific way. It keeps the air pressure over the fuel in the bowl at a normal outside atmospheric level. That is the job of the fuel bowl ventand one of the carburetor's key elements. The next item is the venture, which is a portion of the carburetor's main air passage that momentarily narrows down. Connecting the two is the fuel jet. Here's how it all works. One of the Bernoulli clan, Daniel I think it was, discovered this neat effect that as you accelerate the flow of a set volume of gas, air in this case, you decrease its relative pressure.
So, how can we accelerate our air coming into the engine? As luck would have it, another guy with the name of, you guessed it, Venturi, came along a bit after Bernoulli. This was Giovanni Battista Venturi and he found out that if you took a passageway like a tube, and narrowed it down just a bit in the middle, the air flowing through it would have to accelerate momentarily as it went through the narrowed down portion. It would then return to its normal speed at the other side of the narrow potion. By the way, this is also a subtle effect. Narrowed down too much and we've simply created a restriction to the airflow. But done just a little and the air molecules have to speed up a little so the same amount of them can get through the smaller passageway. They get to the other side where things open up again and they get to slow down and relax once more.
Now, remember Bernoulli's effect; as the airflow accelerates, its pressure drops. It's now less than the normal surrounding atmospheric pressure of 4.1 pounds per square inch. At least that's what it is at sea level. But, the air pressure in the fuel bowl is still at that normal atmospheric level and the difference between the two is what draws the fuel up through the jet passage. Refer figure 2.6.

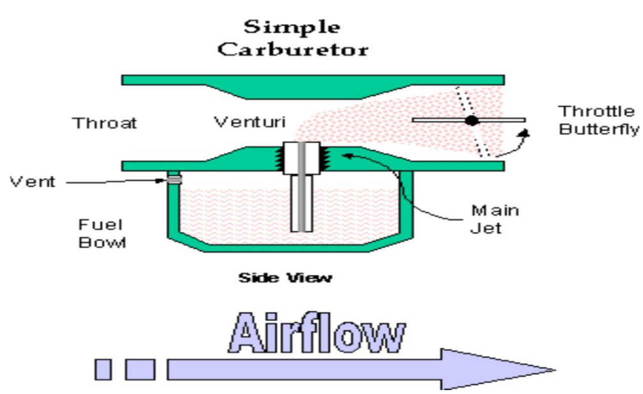


Figure 2.6 Simple carburetor

This is a carburetor in its simplest form and they've been around for quite awhile. The size of the fuel jet in relation to the air passage and venturi are what controls the fuel to air mixture. We're looking for a ratio of approximately 14 parts air to 1 part fuel for our gasoline burning engines. The throttle is there to control the amount of air going into the engine. In fact, many stationary engines have a fixed rate carburetor and don't vary the amount of airflow. We can still control the speed somewhat with the ignition, but again, it's not important for our discussion here. What causes the air to go into the engine in the first place can also be confusing. In a normally aspirated engine (one that isn't supercharged) it's that good old atmospheric pressure again. As the piston goes down, it causes the volumetric size of the cylinder to increase. Now, where we only had a little air space before, we've got a bigger one. Greater volume of space but same amount of air and again we've decreased its pressure. Now if we open up the cylinder to the outside air pressure, air is going to rush in until the pressure in the cylinder is equal to the outside air pressure. As the air rushes in during this process, called the intake stroke, it passes through the carburetor's venturi and draws some fuel along with it. Actually, it's the outside air pressure in the top of the fuel bowl that forces the fuel through the jet.

If the jet does a good job of atomizing the fuel, which means it turns it into a fine spray, the fuel and air will be well mixed as they enter the cylinder. This is the basis really, as our engine is otherwise nothing more than an air pump. We add a bit of fuel to the air, ignite it to push the piston down again and we've got an internal combustion engine[7].

2.16.1 Types of Carburetors

There are different types of carburetors and our is one of the carburetors having a "two-barrel" carburetor which has two bore and two main metering jets. A better distribution of fuel can be obtained with this arrangement. The carburetor is a vital component part to car's engine as that our heart is vital organ to our body. Its job is to feed fuel and air to the cylinders in the correct amounts. New carburetor was purchased from the available auto spare part shop. The purchased carburetor is compatible with the engine we plan to use it on. Next, change to an appropriate carburetor overhaul kit. The kit contains new gaskets, check valves, an accelerator pump plunger and the necessary parts. Best of all, it has detailed instructions and an exploded view of all the parts. Each part is numbered and named for reference. It is very much helpful for reassembly. Before removing the carburetor engine was observed carefully to notice how each and every linkage or hose is attached. The carburetor was unbolted carefully placing small fasteners in proper place.

2.16.2 How carburetor works

Fuel is pumped through the line and enters the carburetor's float bowl. A needle valve admits fuel to the bowl and closes off the flow when the bowl is filled. The valve is opened and closed by a float which rises and falls with the fuel level in the bowl.

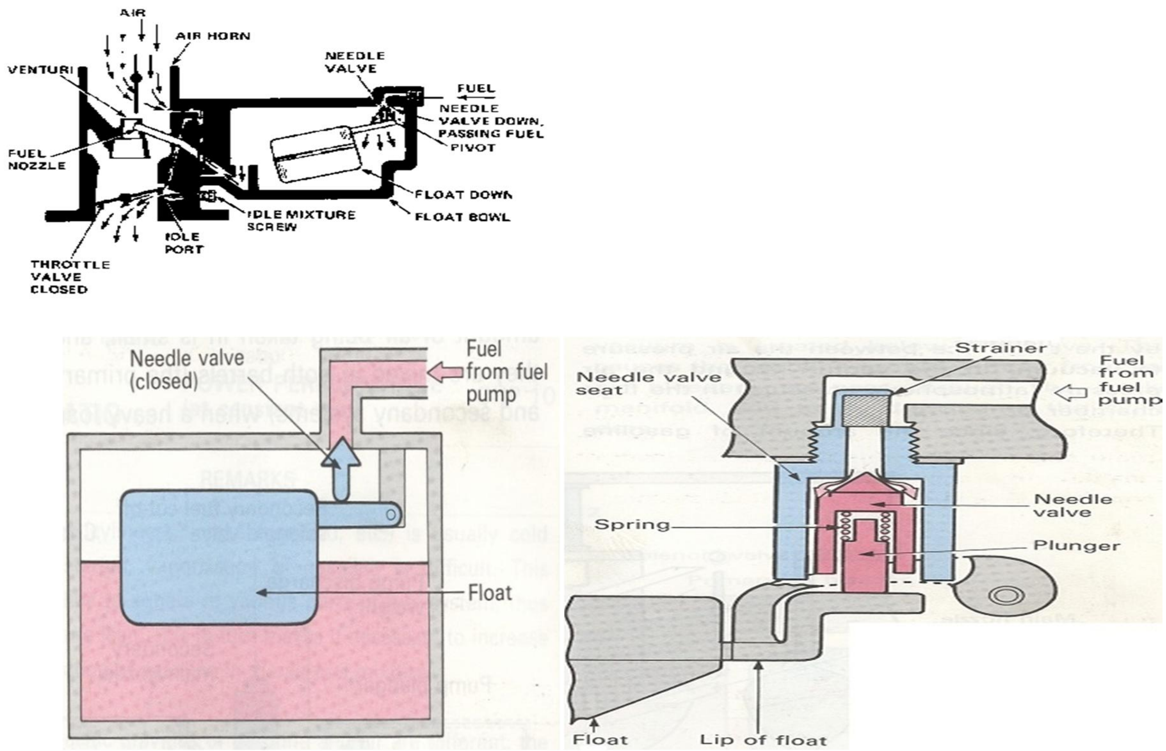


Figure 2.7 Carburetor float, idle and slow system [17]

The fuel level is very critical and must be kept within the close limits by the float and needle valve. Air enters the carburetor through the air horn. It is drawn down past the venture, where the passage narrows. This restriction causes an increase in air velocity and results in the creation of a vacuum below the venture. This vacuum sucks fuel from the bowl through the metering jets. The jets are carefully sized to give the correct ratio of fuel to a given volume of air. Metering rods may be used to partly close the main jets at idle. The metered fuel passes into the venture and is misted into the barrel. Here it is mixed with air and distributed to the cylinders by the way of the intake manifold. A smaller idle passage is equipped with an adjustable jet. The smoothest idle can be obtained by screwing the stem of this jet in or out.

A third fuel passage leads from the accelerator pump, located next to the float bowl. This passage provides an extra shot of fuel only when the accelerator pedal is pressed down. The extra fuel balances the excess air which is sucked in as the throttle plate is suddenly opened during acceleration. The accelerator pump is inactive at idle or when the accelerator pedal is held at a steady position. The choke valve is located in the air horn above the venture. Its purpose is to restrict the amount of air entering the carburetor while the engine is cold. Fuel will not vaporize well in a cold engine and less air flow is desirable. An automatic chock will open and admit more air as the engine heats up. It is necessary to open a manual choke by hand. A gasoline engine runs best with an air/fuel ratio of about 14.5/1. The jets in the carburetor are sized to provide this ratio.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Research Design

The study was conducted at the mechanical and vehicle engineering work shop of Adama Science and Technology University. A series of experiments were conducted on a vehicle equipped with a four cylinder, four strokes, carbureted, water cooled, inline, natural aspirated, spark ignition engine. The experiment involved the following tasks:

- Collecting data like tractive effort, power and fuel consumption for engine running with gasoline, gasoline-ethanol & methanol- ethanol-gasoline blend fuels at different vehicle speeds.
- After the data of tractive effort and wheel power are compiled, the brake power, brake torque, brake specific fuel consumption, and fuel conversion efficiency were determined using the fuel flow reading, the engine speed, and the dynamometer force.
- Then Microsoft Excel is used to graph the data and compare the results for the three different test fuels.

3.2 Materials

3.2.1 Test vehicle and engine specification

Figure 3.1: Toyota corolla KE20 Test vehicle

The data given in the table 3.1 and 3.2 is taken from the manual of the Toyota corolla model KE20.

Table 3.1: Vehicle Specification

Test vehicle specification		
1. Model	*2. KE20(corolla)*	
3. Engine Model	4. 3k	
5. Frame number	*6. KE20-997073*	
7. Color. Trim	*8. 511.ZF22*	
9. Trans axle	10. 4F1.B092	
Transmission	Speed	4 speed
	Gear shift	Manual
	Gearbox model	K 40

The main car and engine technical data are given in Table 3.2 below

Table 3.2 The technical specification of the experiment.

Test engine specification	
Engine model	3K
Number of cylinder	4
Number of valves	8
Bore and stroke(mm)	75x66
Piston displacement	1166 cc/71.2cu.in.
Compression ratio	9.0:1
Firing order	1-3-4-2
Ignition timing(BTDC/rpm)	8^0/600
Cooling system	Liquid cooled
Valve arrangement	Overhead valve
Lubrication system	Forced-feed
Intake charging	Naturally aspiration

Table 3.3.The material required for the project.

Material required for modification of fuel system	Material required to prepare test fuel	Material required for performance test
Carburetor	Graduated cylinder one liter	Compression tester
Carburetor kit	Plastic tanker	Exhaust gas analyzer
Fuel tank	Stiller	Vacuum tester
Fuel pump		Dynamo meter
Fuel filter		Tachometer
Gasoline engine		Ignition timing
Manual choke kit		Speedo meter
Eight (8)feet of fuel hose		
Barb fitting for fuel hose		

3.3 Methodology

It is mostly experimental based and includes the following stages:

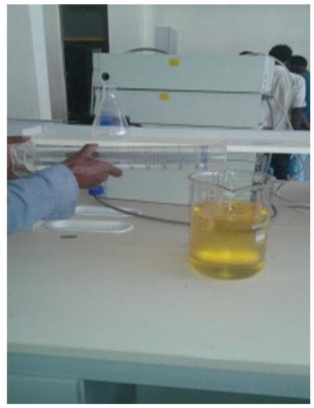
3.3.1 Testing procedure

A series of experiments were carried out using gasoline, and various ethanol/methanol blends. The test blends were prepared just before starting the experiment to ensure that the fuel mixture was homogeneous. The engine was started and allowed to warm up for a period of 20–30 mts. Before running the engine with a new fuel blend, it was allowed to run for sufficient time to consume the remaining fuel from the previous experiment. All the blends were tested under varying speed. The required engine load was obtained through the dynamometer control. The Vehicle speed, fuel consumption, and load were measured, while the brake power, brake torque and brake specific fuel consumption (BSFC) were computed. For each experiment, three runs were performed to obtain an average value of the experimental data.

3.3.2. Test Fuels

We used the following fuels in the experiment

Pure gasoline



10v% Ethanol & 90%v Gasoline blend

2v% methanol, 10v% Ethanol 88% Gasoline blend

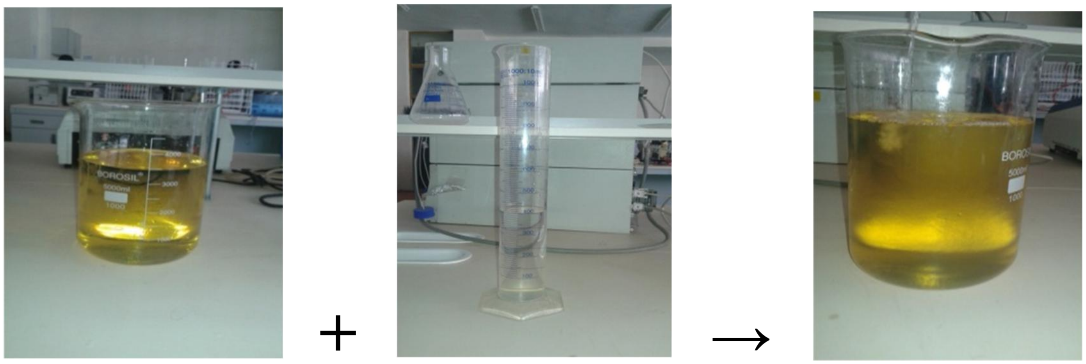
Figure: 3.2 Fuel for test

3.3.3. Preparing test fuel blends

- **Blending gasoline with ethanol**

The procedure we follow to blend the fuel is as follows: Refer figure 3.2 above.

i. Collecting apparatus needed to blend the fuel.
ii. Cleaning the apparatus used to blend the fuel.
iii. Blending 10% ethanol with 90% of gasoline in the graduated cylinder
iv. Stir while blending until it becomes homogeneous
v. Checking phase separation of blend in graduated cylinder



(a) Gasoline (b) Ethanol (c)Gasoline- Ethanol Blend

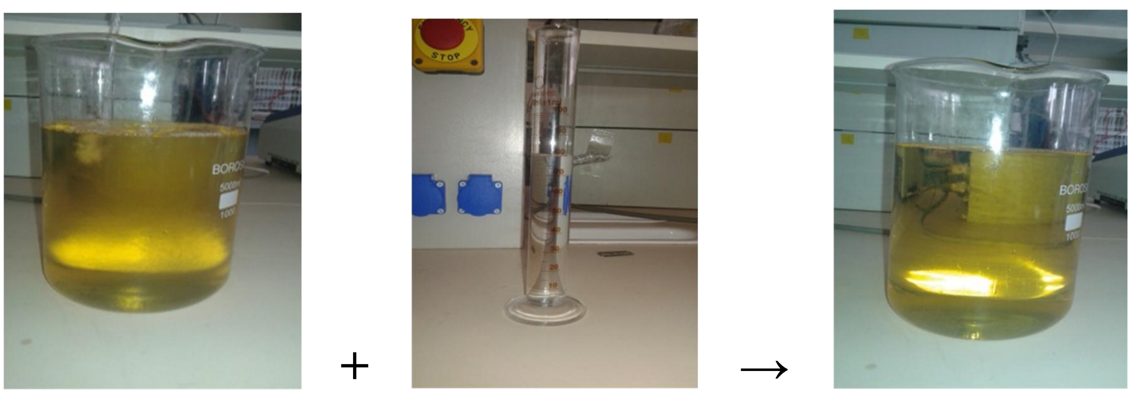
Figure 3.3 Gasoline, Ethanol and blended fuel

Blending gasoline, ethanol and methanol

- In the second step we blend ethanol, gasoline and methanol

i. Blend 10v% ethanol & 88v% Gasoline in the graduated cylinder

ii. Pour the prepared blend in a container.



(a) Blended Gasoline 88%-Ethanol 10% (b) Methanol 2% (C) Gasoline 88% Ethanol 10% & Methanol2%

Figures 3.4 Gasoline-Ethanol-Methanol Blend as a fuel

iii. Blend 98% of ethanol-gasoline blend with 2% of methanol and keep this blend in the graduated cylinder for 24 hours to check whether it separates or not. It was kept in freezer at different temperatures to check for phase separation.

3.3.4 Modification of fuel system

❖ **Increasing fuel main jets diameter**.

The following are the modifications done to the fuel system.

- Adjusting float bowl by bending the float.
- Replacing fuel lines with plastic tube which is compatible with methanol and ethanol.

Figure 3.5 Plastic tube used for fuel line

- Changing the previously used gasoline fuel tank to store the ethanol-methanol -gasoline blend.

3.4 Experimental Procedure

3.4.1 Data Acquisition

Three sets of engine experiments were performed to evaluate the power. The experiments were conducted for pure gasoline, 10% ethanol 90%gasoline blend and 2% methanol 10% ethanol and 88% gasoline blend fuel in one litter. In all settings, the experiments were conducted as per the steps given below.

Steps 1 – Fuel blends were prepared by volume. The appropriate amount of ethanol was taken and then added to the gasoline (applied for the ethanol blends only).

Step 2 –The engine fuel tank was cleaned and filled with the fuel to be tested.

Figure 3.6 Fuel to be tested

Step 3 – The engine was run with the test fuel for about three minutes to get warm up and stabilize.

Step 4 –The fuel consumption, tractive force and power at the rear wheel were recorded

Note: - All the tests were performed on the same day.

3.4.2 Vehicle testing procedure

For obtaining the performance map, the engine is started with gasoline, and the engine was stabilized a while to reach a stable state. In this state, the engine is set in full throttle and maximum power is applied to it. The vehicle was driven on the chassis dynamometer and the tractive effort and wheel power is measured at test speed selected with 5Km/hr intervals starting from 25 Km/hr. 25 Km/hr is the minimum speed with which test can be done on the sun Road-a-Matic XII chassis dynamometer. The experiment was conducted in first gear, second gear, third gear and fourth gear. The time is taken for the consumption of fuel in CC and recorded.

Figure 3.7 Fuel consumption measurements

Experiments were performed with three different fuels at 25, 30,35,40,45, 50…100km/h of full load for different gear speed whose fuels were pure gasoline , gasoline-ethanol and gasoline-ethanol- methanol

CHAPTER FOUR

4. MODIFICATION

4.1 Gasoline Fuel tank

One of the drawbacks of alcohols as a fuel is corrosive to some metals, including aluminum. This reciprocal process effectively fuels corrosion until either the metal is eaten away or the concentration of CH_3OH is negligible. Concerns with methanol's corrosives in a blend which creates oxidation so we select a plastic container available in the market made of fluorocarbon (polymer) and which is suitable as a fuel tank for ethanol - gasoline - methanol blend is used instead of the former gasoline fuel tank which is made of metal since ethanol and methanol corrodes more.

4.2. Modification of the Carburetor

4.2.1 Disassembling the Carburetor

Carburetor rebuild kit includes a detailed diagram of carburetor unit. Carburetor was disassembled, cleaned and overhauled. All the parts like fuel metering jets, including: main jet, pilot (idle) jet, float, main body and throttle body are identified.

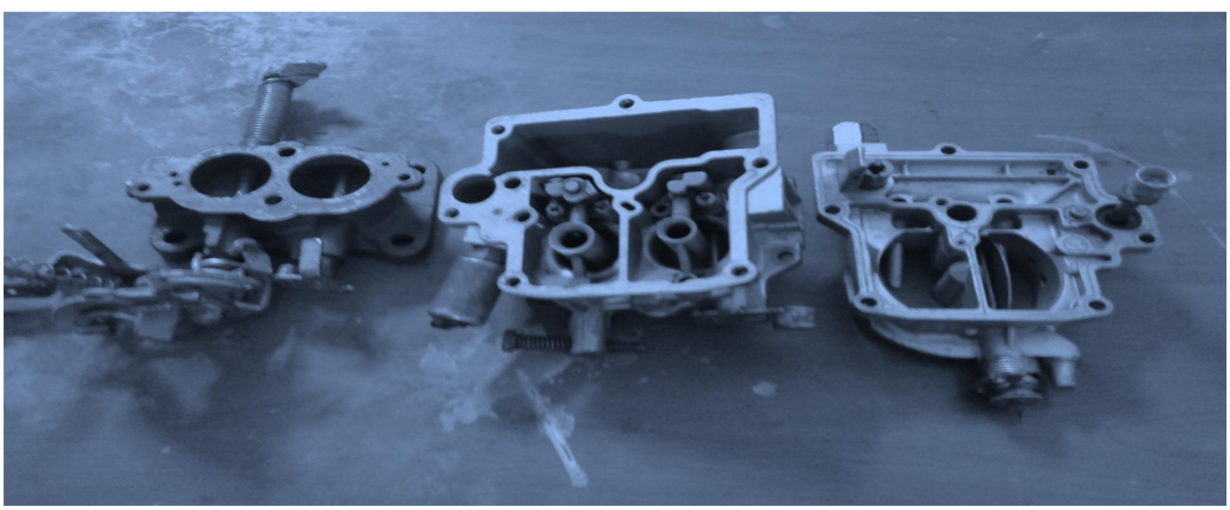


Figure 4.1 Component parts of carburetor[11].

4.2.2 Enlarging the Metering Jets

Clean and uncluttered table was used to work on. The exploded view is used as a guide and disassemble the carburetor far enough to remove the main, metering jets. The jets are more accessible in some models than others. Jets are stamped with the orifice diameter in metric or English units. For the 3k Toyota corolla the jets are stamped in metric units. Primary main jet number 141 & secondary main jet number 105 that mean 1.41 mm & 1.05 mm.

141 means 1.41 mm = 0.056 inch

105 means 1.05 mm = 0.0413 inch

In some models of carburetor jets are stamped in U.S. units, 50 indicates .050 inch. There are exceptions; check with a carburetor shop to be sure. Convert millimeters to inches by dividing by 25.4. Multiply the jet sizes by the conversion factor. New jets of the proper size which are available in the market are procured. The hole sizes of the metering jets are carefully determined. Shop manual was referred for measuring the size of the jet. We have two alternatives; the first alternative is to take the jets to an automotive machine shop. They have the tools to measure and enlarge the jets. Jets sizes are determined as shown below. This is the calculation we used from the Dodge

Figure4.2 Main metering jets

Original jet diameter 0.056 inch

Increase jet diameter by 10%

Therefore the correct primary jet size 1.1 x 0.056 = 0.0616 inch = 1.56464 mm

Original secondary jet diameter 0.0413 inch

Increase jet diameter by 10%

Therefore the correct secondary jet size is 1.1 x 0.0413 = 0.0454 inch = 1.1539 mm

Next we looked up 0.0616 inch for primary & 0.0454 inch for the secondary jets in a standard drill size chart. This chart is available in most auto repair manuals or machinists handbooks. The other alternative is to purchase the jet. The jets of required sizes were purchased[14].

4.2.3 Float Modifications

In flow-jet carburetors, the float controls the operation of the inlet needle and seat. As the name implies, the float "floats" on top of the fuel in the carburetor bowl. Based on the float level adjustment, the float position will either shut off the fuel supply via the inlet needle and seat or pull the needle valves. Gasoline- ethanol and methanol blend is heavier and denser than gasoline. The float will ride higher in a given amount of Gasoline -ethanol and methanol blend than in the same amount of gasoline. Since fuel flow is cut off when the float rises to a specific point, the Gasoline ethanol and methanol blend level will be lower than if the float bowl were filled with gasoline. Some method must be used to raise the fuel level to normal. Otherwise, the engine will cut out during turns due to lack of sufficient fuel.

A carburetor is just a fancy siphon. The piston creates a vacuum that siphons gas out of the float bowl through the various jets. If the level is low, the bike will run lean because the gas must siphon too high on a given vacuum. If the level is high, it siphons too much and runs rich. If the level is erratic (sticky float hinge) it can act lean, then rich, and back again driving you nuts. If the level is way too high, the floats may not stop gas flow and the engine and air box may take on fuel. Gas may flow until the tank runs dry. Some cars have overflow tubes so it just runs out on the ground. Changing the float height changes the level of the fuel in the float bowl. There are two mechanism of float adjustment to increase or decrease the amount of fuel in bowl:-

- bending the float linkage and
- adding weight to the float.

❖ Bending the Float Linkage

Gasoline- ethanol and methanol blend is heavier and denser than gasoline and this raises the bowl which close needle valves. In our case the linkage between the float and the inlet valve was bent to make float bowl close inlet valves late so as to increase the amount of fuel in bowl. The amount by which the linkage to be bent is determined by trial and error method. Several settings are tried to find the correct float height. Refer figure 4.3.

Figure 4.3 Bending the Float Linkage

- Adding Weight to the Float

Difficult but more accurate method is to add weight to the float. Carefully weigh the whole float assembly on a balance. Weigh a piece of solder or epoxy glue equal to 10% of the total weight of the float assembly. Fasten this to the top of the float, distributing the weight as evenly as possible. We tried both methods. The bending method was tedious and involved disassemble of the carburetor several times before the correct setting was found. The weight method worked just fine. It is preferable because we can set the float just as the instructions in the overhaul kit call for. We reassemble the carburetor and follow the kit guidelines for reassembly and adjustment

4.2.4 Ignition System Modification

Once the fuel system mixes the proper ratio of air to fuel and delivers the mixture to the individual cylinders, its function is completed. The actual firing and production of usable power is controlled by the ignition system. Its task is to ignite the fuel/air mixture at a precise instant in relation to the movement of the piston. If the mixture fires too early, pre-ignition pinging will occur and may damage the engine. If the mixture ignites too late, power will be lost and fuel gets wasted. A gasoline engine is timed to fire just as the piston reaches the top of its stroke or just an instant before. Gasoline ignites and burns so rapidly that the result is more like an explosion than a burning. Gasoline ethanol and methanol blend burns at a much more even rate. It is easy to ignite and requires less time to completely vaporize and burn. To allow for this less time, it is necessary to "retard" (cause to fire late) the timing of the engine.

We did this by loosening the distributor and turning it in the same direction of its rotation. Here is how we did it:

1. We loosen the bolt at the base of the distributor until the whole unit can be turned.
2. Then we initially retard the timing by turning the distributor about 1/16 of a turn and snug the hold-down bolt so the distributor won't turn itself (but we can still move it with a little effort).

Figure 4.4 Ignition timing adjustment

3. We start the engine and run any gasoline remaining out of the fuel line. Now we retarded it still more until we get a slower idle, but still a smooth idle.

We checked the timing by driving and we heard "pinging" in the engine during acceleration, so we "retarded" the timing. The correct setting was just below the point where the pinging disappears. We initially time the car by hearing the sound and made several changes in timing before we were completely satisfied. After several days of testing we checked the timing with a light. The original setting had been 8º bTDC (top dead center). After we convert it to gasoline ethanol and methanol blend, the optimum setting had become 5º bTDC because of that a fuel used for test have more ignitibility than the conventional one.

CHAPTER FIVE

5. RESULTAND DISCUSSION

5.1 Phase Separation

In our test,there is no phase separation for the blended fuels of the E10, M2 and G88 in twenty four hours in varies atmosperic temprature. But one important thing to remember is that the total alcohol concentration will determine the phase separation lines. So that,it needs more test if more/less concentration of alcohols is used.

Figure 5.1Checking phase separation of gasoline, ethanol and methanol blend

In current condition the blend of ethanol - gasoline in Ethiopia is 5% ethanol & 95% gasoline, but these blend is not all over the country due to lack of ethanol. There is only two sugar factory which produce ethanol which are Fincha & Mathara. In some part of the country they use pure gasoline. For the future the availability of ethanol increases, because of other sugar factory such as Tendaho, Wenji, Dufti …almost about 10 sugar factories are building production units of ethanol. When they begin to produce ethanol the deficiency may not exist. We increase this percentage in to 10% of ethanol & 88% of gasoline and 2% methanol.

Comparison of fuel cost

Table 5.1 Comparison of fuel cost

No.	Fuel	Quantity	Unit	Price/liter
1	Pure gasoline	1	Liter	18
2	Ethanol	1	Liter	13.48
3	Methanol	1	Liter	9
3	10E%,2M% blend with 88%G	1	Liter	11.988

5.2 Evaluation of Torque

There are two basic types of dynamometers, the engine dynamometer and the rolling road or chassis dynamometer. The rolling road is very convenient as it requires only driving a car on to a set of rollers and run the engine to find the power and torque output.

Sun road –a-matic XII chassis dynamometer has been used for the current research. The chassis dynamometer is capable of measuring the power output and tractive effort applied at the drive wheels. The power actually available at the engine crankshaft, called the brake power, can be computed if the transmission losses and drive train gear ratios are known. The tractive effort recorded at the drive wheels can later be used to determine the torque produced by the engine. A relation for converting the tractive effort at the wheels to torque can be used once the radius of the drive wheels is known.

Figure 5.2 Theisun road- a-mattic XII chassis dynamometer

5.2.1 Tractive effort and wheel power

The force available at the contact between the rear wheel tires and road is known as tractive effort. Tractive effort (F) of gasoline, ethanol–gasoline & methanol-ethanol-gasoline blend obtained from the chassis dynamometer test is presented in table 5.2, 5.3 and 5.4. Wheel power is given in table 5.5, 5.6 and 5.7.

When the vehicle is driven with gasoline fuel in first gear with full throttle, the engine is running at its maximum speed. When the vehicle is driven by 25 km/hr, in first gear, the engine rpm is 3999.3 rpm. At 30 km/hr rpm reaches 4799.2 rpm, and at 35 km/hr engine runs at 5599 rpm. When the vehicle is running with methanol- ethanol and gasoline blend fuel the maximum tractive force is obtained at first gear. The tractive force registered by dynamo meter in the each gear for gasoline, ethanol-gasoline & methanol-ethanol-gasoline is slightly different when the vehicle is driven at different speeds. The fact that ethanol-gasoline is supplied to the engine will make the situation even worse because ethanol-gasoline needs a little time to be mixed with air. Consequently, when the engine is running at first gear tractive effort is increased and the wheel power of gasoline, ethanol-gasoline and methanol-ethanol- gasoline blend is almost equal for 25km/hr. But at high rpm the power at the wheel of methanol-ethanol-gasoline is higher than gasoline & ethanol-gasoline blend fuels registered by the chassis dynamometer. In addition, at high engine speed, friction increases significantly. The rise of friction reduces the power at the rear. The main reason for wheel power reduction is that due to the raise of friction this heat loss, these reduces the power at the wheel. The heat loss through the exhaust also increases as the speed increase, thus reducing tractive effort. The tractive efforts at different gears have a behavior of increasing for a while and then drops.

Table 5.2 Tractive effort when vehicle running with Gasoline fuel.

Vehicle speed	Tractive effort (kN)			
Km/hr	1st gear	2nd gear	3r gear	4th gear
25	1.55	1.3	1.25	1
30	1.5	1.2	1.15	0.95
35	1.2	1.12	1.11	0.9
40	1.12	1.11	1	0.85
45		1	0.9	0.8
50		1.55	1.2	0.75
55		0.7	1.15	0.74
60		0.6	1.1	0.65
65		0.45	1.1	0.6
70		0.4	1	0.58
75			1	0.55
80			0.9	0.5
85			0.85	0.48
90			0.75	0.45
95				0.4
100				0.1

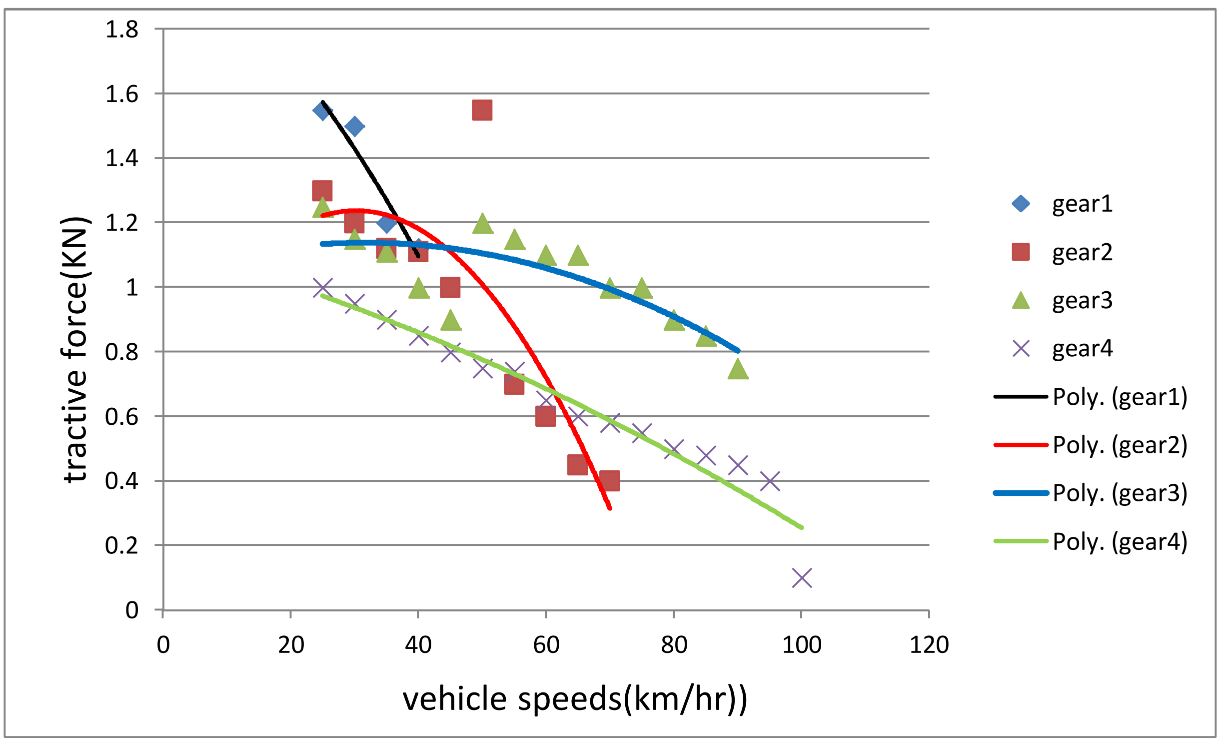


Figure 5.3 Tractive Efforts

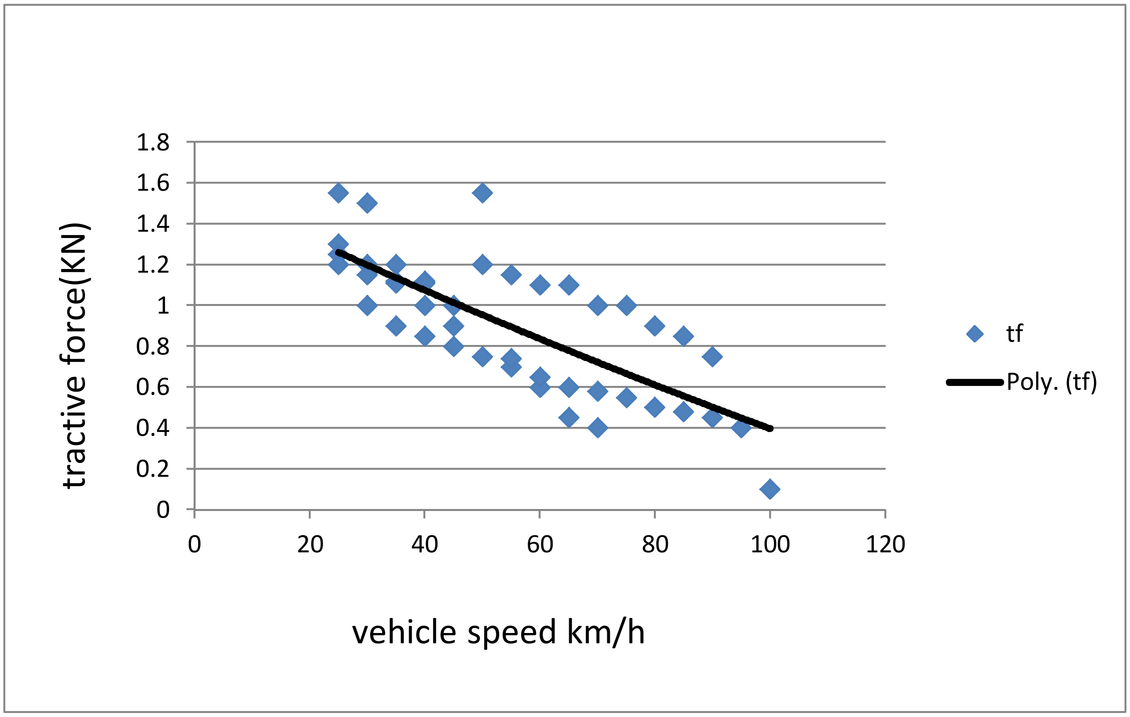


Figure5:4 Average Tractive effort when vehicle running with Gasoline fuel.

Table: 5.3 Tractive efforts when vehicle running with ethanol-methanol-gasoline fuel.

Vehicle speed	Tractive effort (kN)			
Km/hr	1[st]gear	2[nd]gear	3[r]gear	4[th]gear
25	1.32	1.6	0.25	0.85
30	1.2	1.55	1.5	0.8
35	1.11	1.5	0.5	1.2
40		1.5	0.5	1.5
45		1.6	0.45	0.75
50		1.4	0.4	0.8
55		0.75	1.15	0.8
60		0.725	1.15	0.75
65		0.3	1.1	0.75
70		0.3	0.1	0.9
75			1	0.65
80			0.9	0.5
85			0.5	0.3
90			0.4	0.3
95				0.7
100				

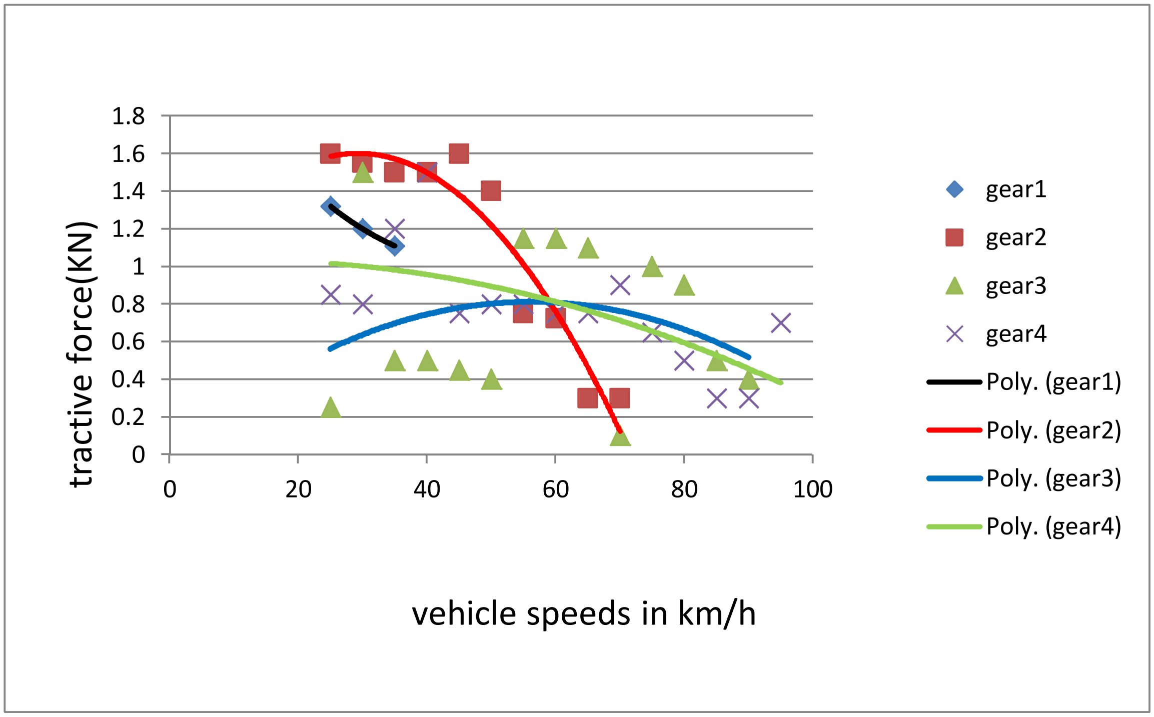


Figure: 5.5 Tractive efforts

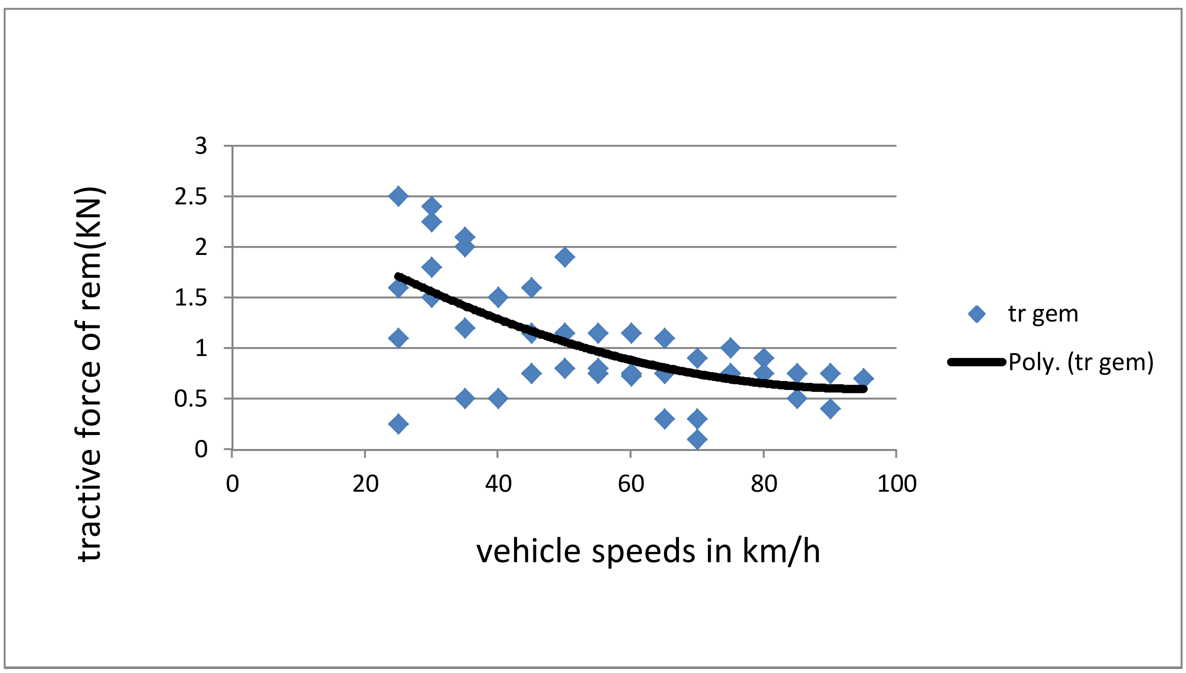


Figure 5.6 Average tractive efforts when vehicle running with ethanol-methanol-gasoline fuel.

Table5.4 Tractive effort when vehicle running with Ethanol-Gasoline fuel.

Vehicle speed	Tractive effort (kN)			
Km/hr	1st gear	2nd gear	3r gear	4th gear
25	2	2	1.8	1.45
30	1.8	1.75	0.7	1.5
35	1.6	1.54	0.5	1.3
40		1.45	0.5	1.2
45		1.6	0.5	1.1
50		1.9	1.1	1
55		0.75	1.1	1.3
60		0.73	1.1	1.4
65		0.7	1.08	1.5
70		0.7	1	0.8
75			0.95	0.8
80			0.5	0.8
85			0.4	0.78
90			0.35	0.75
95				0.7
100				0.7

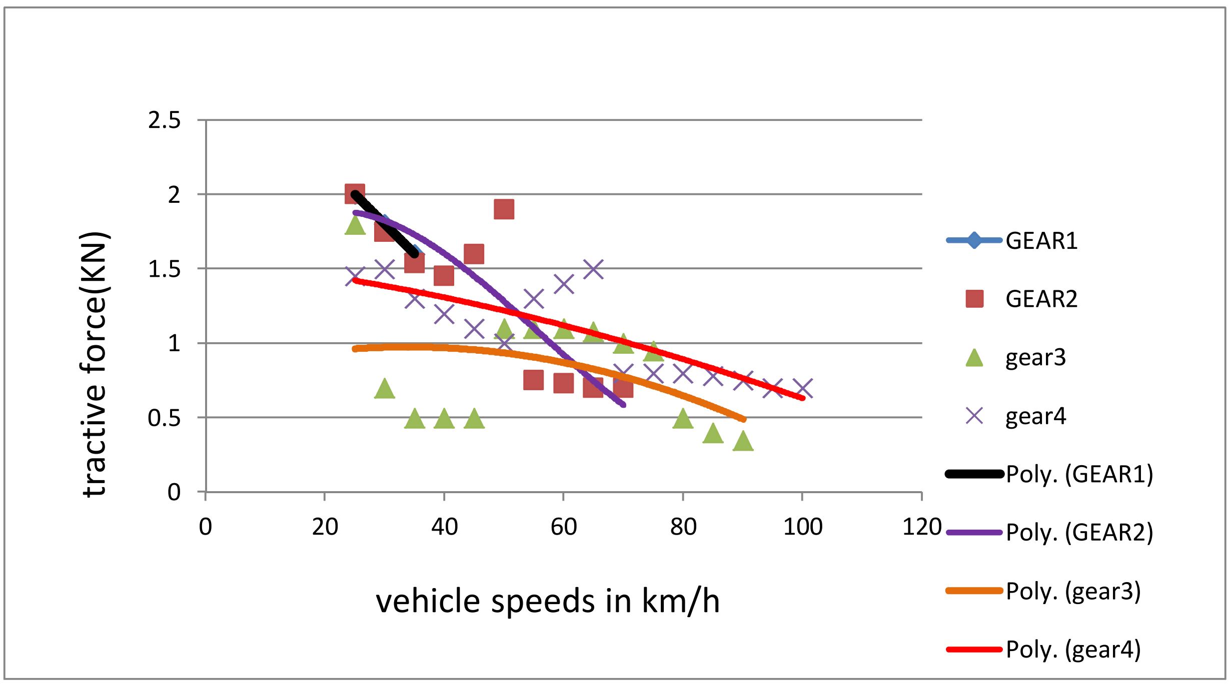


Figure :5.7 Tractive effort .

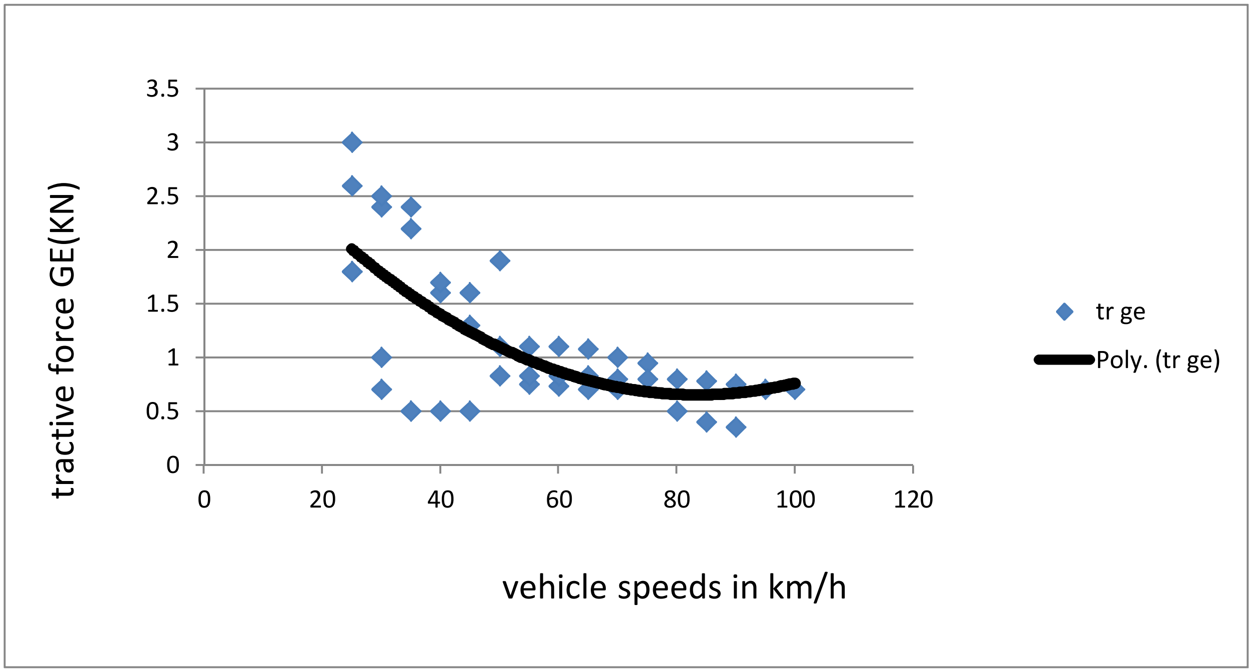


Figure :5.8 Average tractive effort when vehicle running with Ethanol-Gasoline fuel.

Table 5.5 Wheel Power when vehicle running with Gasoline fuel.

Vehicle speed	Wheel power (kW)			
Km/hr	1st gear	2nd gear	3rd gear	4th gear
25	12	12	11	11
30	11	10	10.5	11
35	10	19.75	11	6.5
40	10	12	10	21
45		22	15	10
50		13	16.5	11.3
55		10	18	12.3
60		9.7	20	14
65		9.2	20	14
70		8.8	20	16
75			18	17
80			12	18
85			10	19.3
90			9	20
95				20
100				20

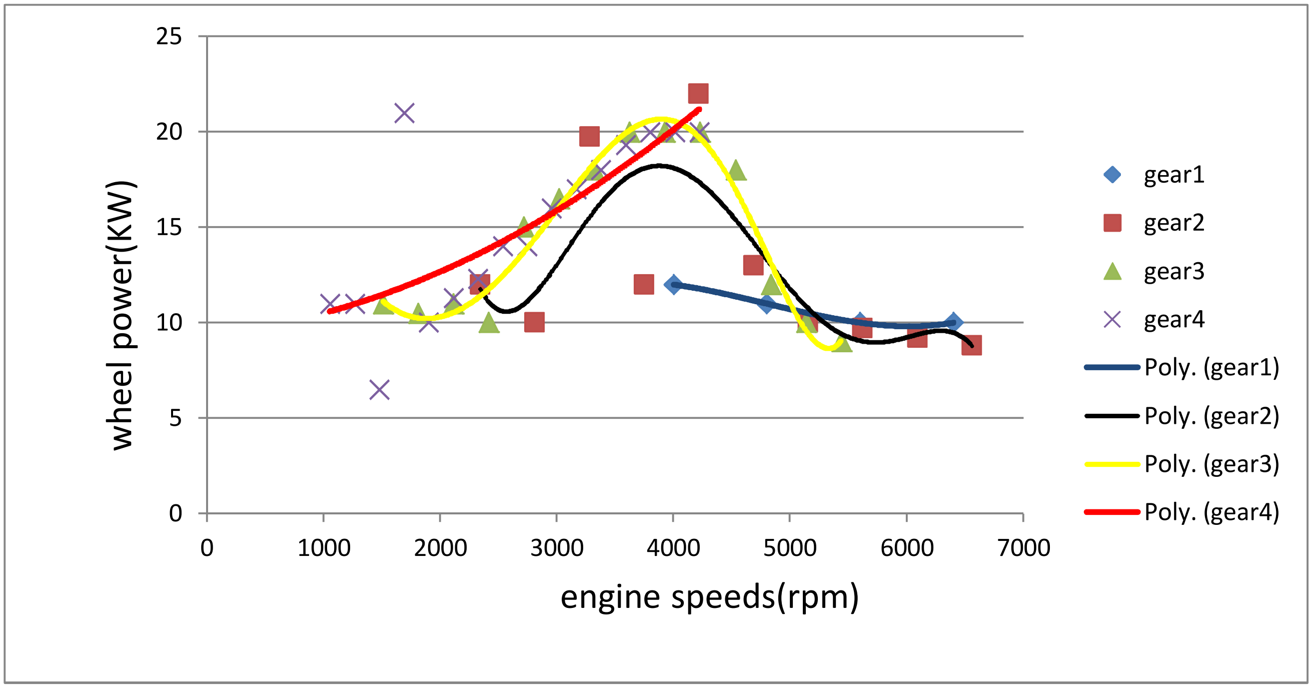


Figure 5.9 Wheel Power

Table 5.6 Wheel Power of when vehicle running with Ethanol-Methanol-Gasoline fuel

Vehicle speed	Wheel Power (kW)			
Km/hr	1st gear	2nd gear	3rd Gear	4th gear
25	12	22	8	4
30	8	20	16	21
35	10	20	10	20
40		18	10	18
45		24	4	22
50		23	18	11
55		12	19	12
60		10	20	13
65		9.7	21	14
70			20	10
75			21	16
80			20	17
85			10	18
90			8	19.3
95				19.5
100				19.5

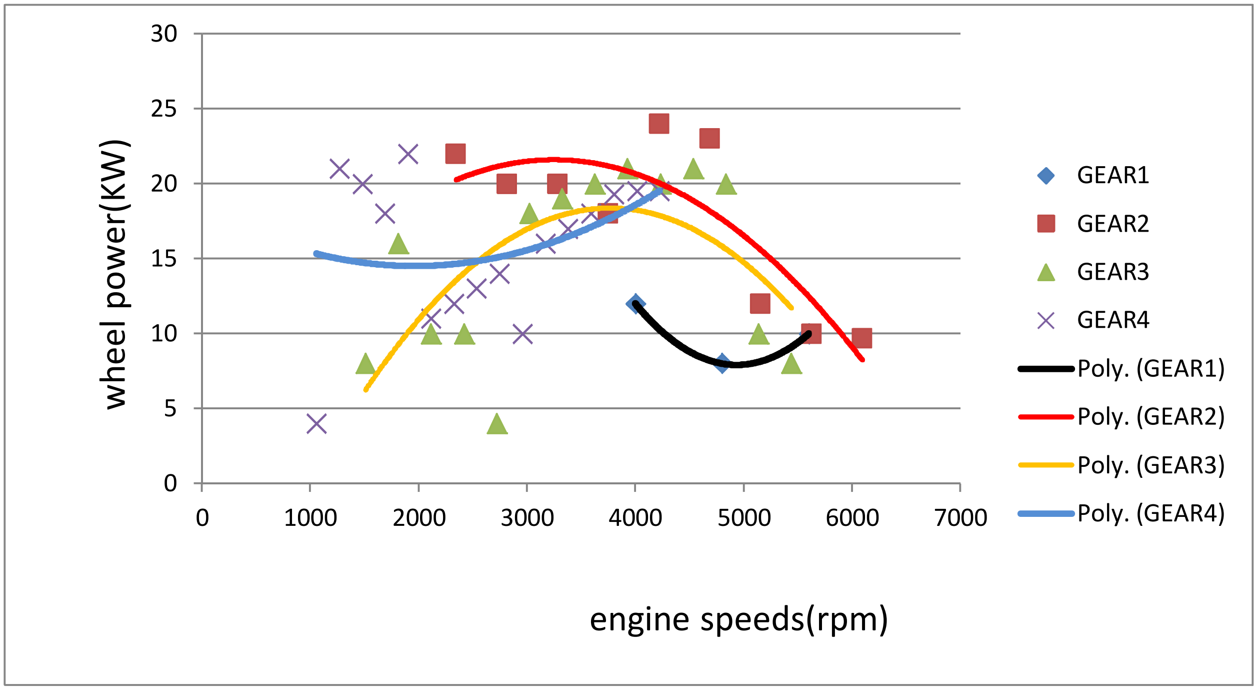


Figure: 5.10 Wheel Power of when vehicle running with Ethanol-Methanol-Gasoline fuel

Table5.7 Wheel Power when vehicle running of with Ethanol-Gasoline fuel.

Vehicle speed	Wheel Power (kW)			
Km/hr	1st gear	2nd gear	3rd Gear	4th gear
25	12	20	8	21
30	8	20	10	21
35	10	21	8	18
40		18	6	18
45		18	10	18
50		23	18	11
55		12	19	12
60		10	20	13
65		9.7	21	14
70			20	10
75			21	16
80			20	17
85			10	18
90			8	19.3
95				19.5
100				19.5

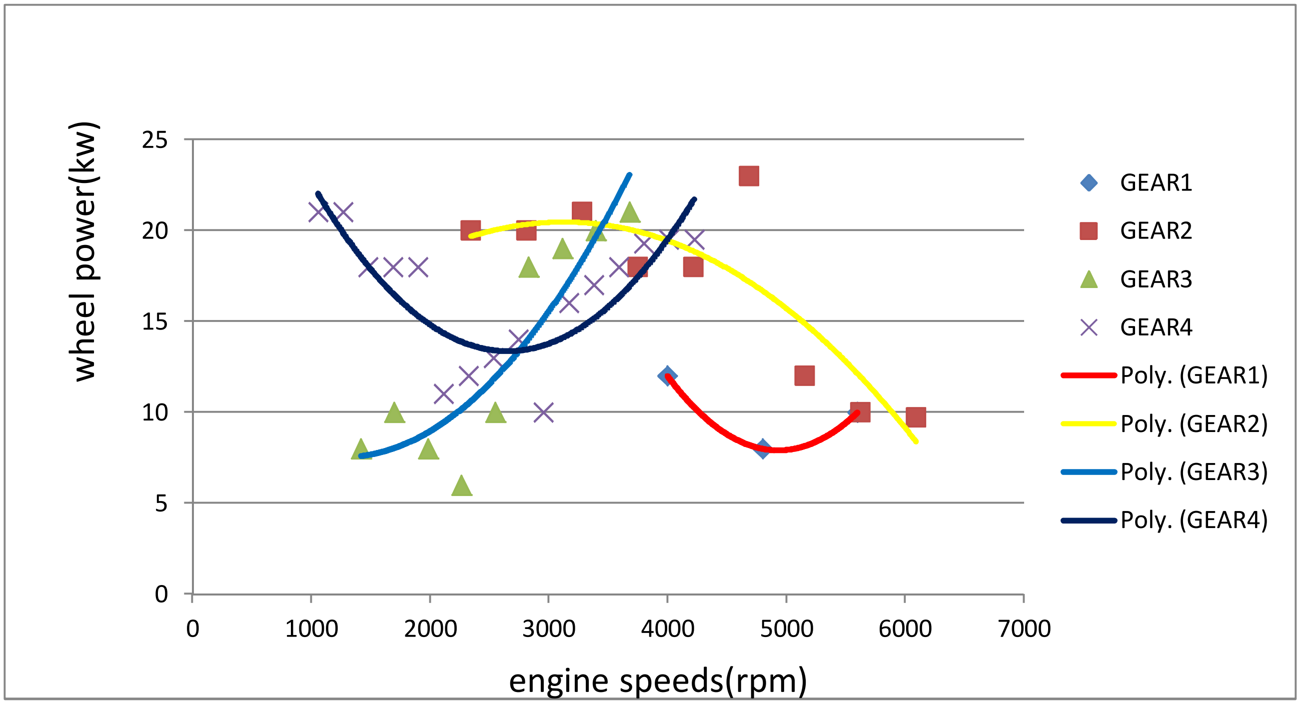


Figure: 5.11.Wheel Power

Wheel torque

$$F = \frac{T_w}{r} \quad \text{……………………………………………………………………...} \quad (1)$$

$$T_w = F \times r \quad \text{……………………………………………………………………………} \quad (2)$$

Where F= tractive effort

T_w= Torque at rear wheel

r = radius of tire in meter

The radius of the rear tire is measured to be 0.265 meters. Inserting the obtained radius in the above equation and computing for torque at the wheels gives the results presented in table: 5.8, 5.9 and 5.10 [25]

Table 5.8 Wheel torque when vehicle running with Gasoline fuel

Vehicle speed	Wheel torque (Nm)			
Km/hr	1st gear	2nd gear	3rd Gear	4thGear
25	424	291.5	477	344.5
30	397.5	318	304.75	79.5
35	265	477	318	212
40		556.5	132.5	556.5
45		424	318	219.95
50		371	318	219.95
55		159	304.75	219.95
60		132.5	291.5	219.95
65		79.5	291.5	212
70		79.5	265	212
75			265	212
80			238.5	206.7
85			225.25	219.95
90			198.75	198.75
95				185.5
100				185.5

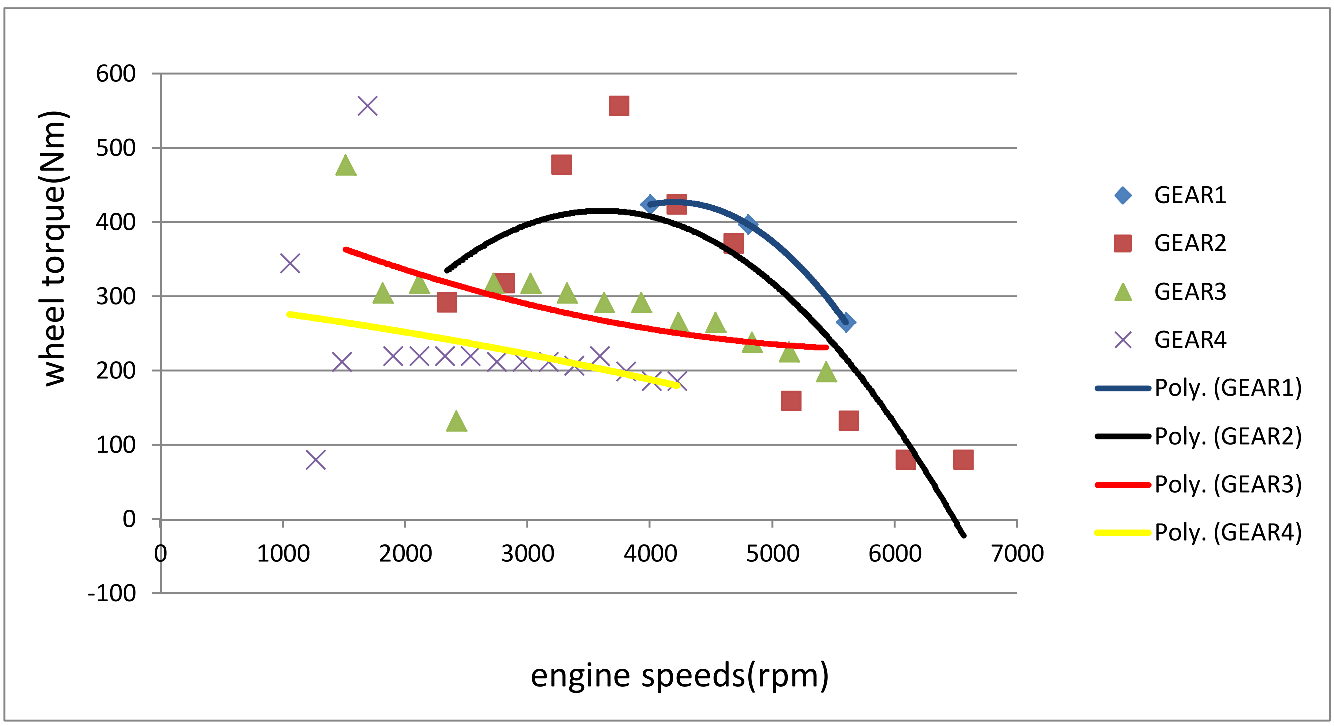


Figure: 5.12. Wheel torque (Nm)

Table 5.9 Wheel torque when vehicle running with Ethanol -Gasoline fuel

Vehicle speed	Wheel torque (Nm)			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	477	795	477	689
30	265	636	185.5	662.5
35	132.5	583	132.5	636
40		424	132.5	450.5
45		424	132.5	344.5
50		503.5	291.5	219.95
55		198.75	291.5	219.95
60		193.45	291.5	219.95
65		185.5	286.2	219.95
70		185.5	265	212
75			251.75	212
80			132.5	212
85			106	206.7
90			92.75	198.75
95				185.5
100				185.5

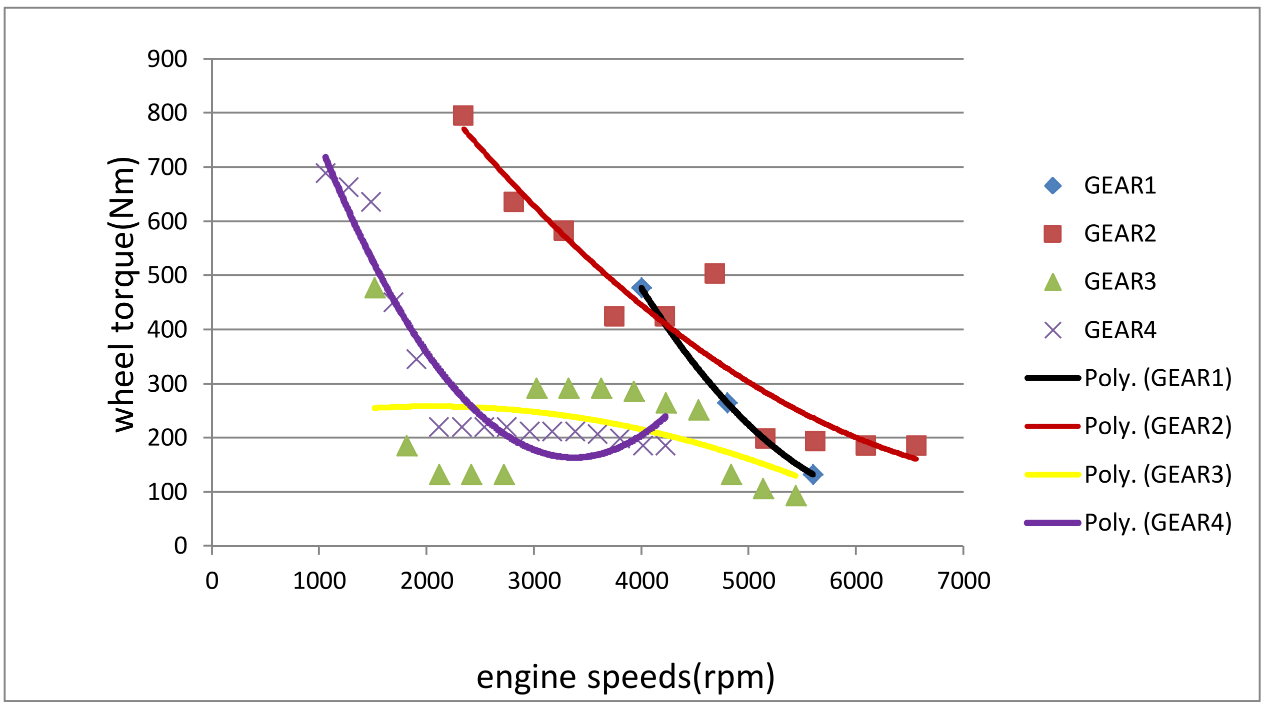


Figure: 5.13 Wheel torque

Table: 5.10 Wheel torque when vehicle running with Ethanol-Methanol-Gasoline

Vehicle speed	Wheel torque (Nm)			
Km/hr	1st gear	2nd gear	3rd Gear	4thGear
25	132.5	424	66.25	291.5
30	132.5	636	477	662.5
35	132.5	556.5	132.5	583
40		397.5	132.5	397.5
45		424	304.75	463.75
50		503.5	304.75	212
55		198.75	304.75	212
60		66.25	304.75	198.75
65		79.5	291.5	198.75
70		79.5	26.5	238.5
75			265	198.75
80			238.5	198.75
85			132.5	198.75
90			106	198.75
95				185.5
100				185.5

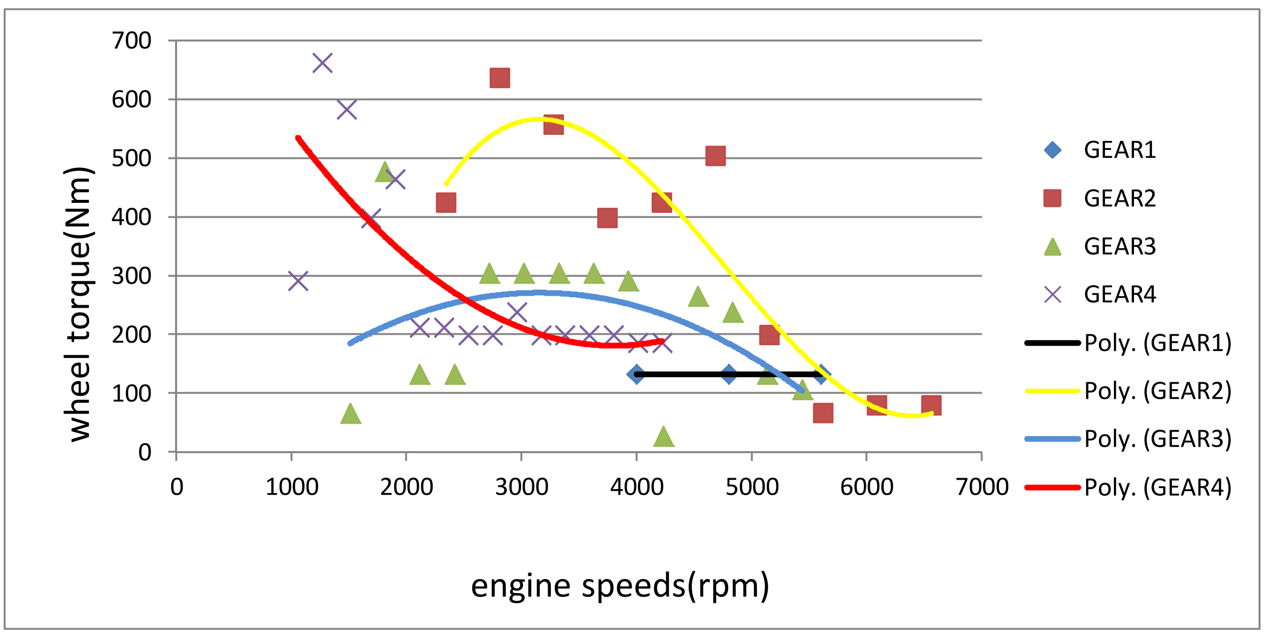


Figure: 5.14 Wheel torque

Brake torque (T_b)

Once the torque at the wheel is known the brake torque can be calculated by using the following

$T_w = (g.r \times a.r)\, \eta_t \times T_b$ ………………………………………..………………… (3)

$T_b = \frac{T_w}{(g.r \times a.r)\eta t}$ ………………………………………………………………….. (4)

Where T_w = torque at rear wheels

g.r = gearbox gear ratio

a.r = back axle ratio

η_t = overall transmission efficiency

T_b = brake torque

The test vehicle (Toyota corolla model KE20) uses manual gear box type K40. This is a 4 speed transmission with the following gear ratios:

Table 5.11 Vehicle gear ratio

Gear	1st	2nd	3rd	4th
Gear ratio	3.789	2.220	1.435	1
Back axle ratio				4.222

For torque at the tire surface transmission efficiency of 0.90 at top gear and 0.80 at other gears can be assumed. After finding the brake torque at different gears, the brake torque verses engine speed graph can be drawn. The chassis dynamometer used for the test does not have engine revolution counter, it rather displays wheel speed in Km/hr. It is therefore necessary to calculate the engine speed (N) from the wheel speed.

Depending on the gear selected, there is speed reduction from the engine to drive wheels consequently the engine speed for each gear has to be treated separately. The relationship between engine revolution (N) and vehicle speed (V) depends on the overall gear ratio.

The engine revolution and vehicle speed can be related with the following expression:

The driving speed is:

$$\frac{2\pi rN}{g.rxa.r} = \frac{1000V(km/hr)}{6\ 0} \quad \text{.. (5)}$$

$$N = \frac{vxg.rxa.rx1000(rev/min)}{CRx6\ 0} \quad \text{.. (6)}$$

$$N = \frac{2.65xvxg.rxa.r(rev/min)}{r} \quad \text{.. (7)}$$

Where CR = the driving wheel circumference in m = 2π x tyre radius (r)

N = the engine speed in rpm

g.r = gear box ratio

a.r = back axle ratio

The radius of the test vehicles rear tire is measured to be 0.265 m; the gear ratios of each speed and the axle gear ratios are as shown in the table 5.11 and hence can be substituted in equation (7) to calculate N.

Once the values of engine speed are found, brake torque versus engine speed graph can be constructed. Figure 5.12, 5.13 and 5.14 show the brake torque curves obtained. When running on a gasoline, a maximum brake torque of 99.4 Nm found at 1815.5rpm.

Table: 5.12 Brake torque when vehicle running with Gasoline fuel

Vehicle speed	Brake torque (Nm)			
Km/hr	1st gear	2nd gear	3rd Gear	4thGear
25	21.24	38.9	99.4	50.7
30	31	42.4	63.5	20.9
35	20.7	63.6	66.25	55.8
40		74.25	27.6	146
45		56.6	66.25	57.9
50		49.5	66.25	57.9
55		21.2	63.5	57.9
60		17.7	60.7	57.9
65		10.6	60.7	55.8
70		10.6	55.2	55.8
75			55.2	55.8
80			49.7	54.4
85			46.9	57.9
90			41.4	52.3
95				48.8
100				48.8

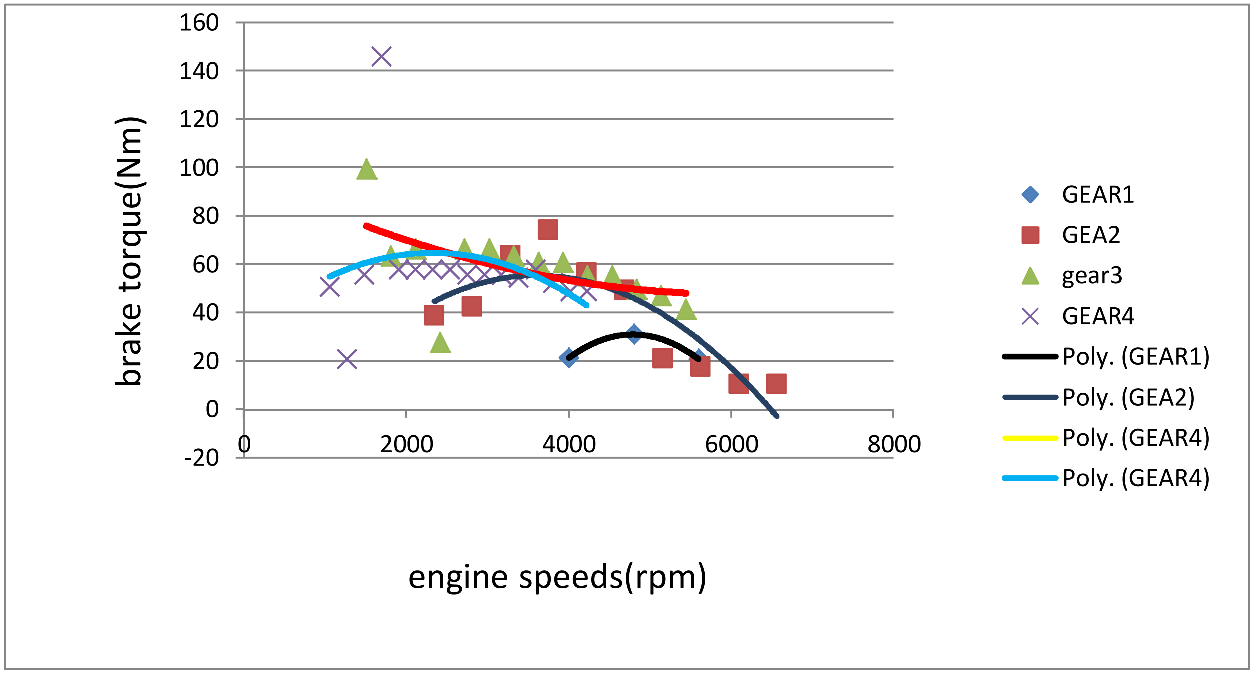


Figure: 5.15 Brake torque

When running on gasoline, the maximum brake torque of 63.5 Nm was found at 1812.5rpm.

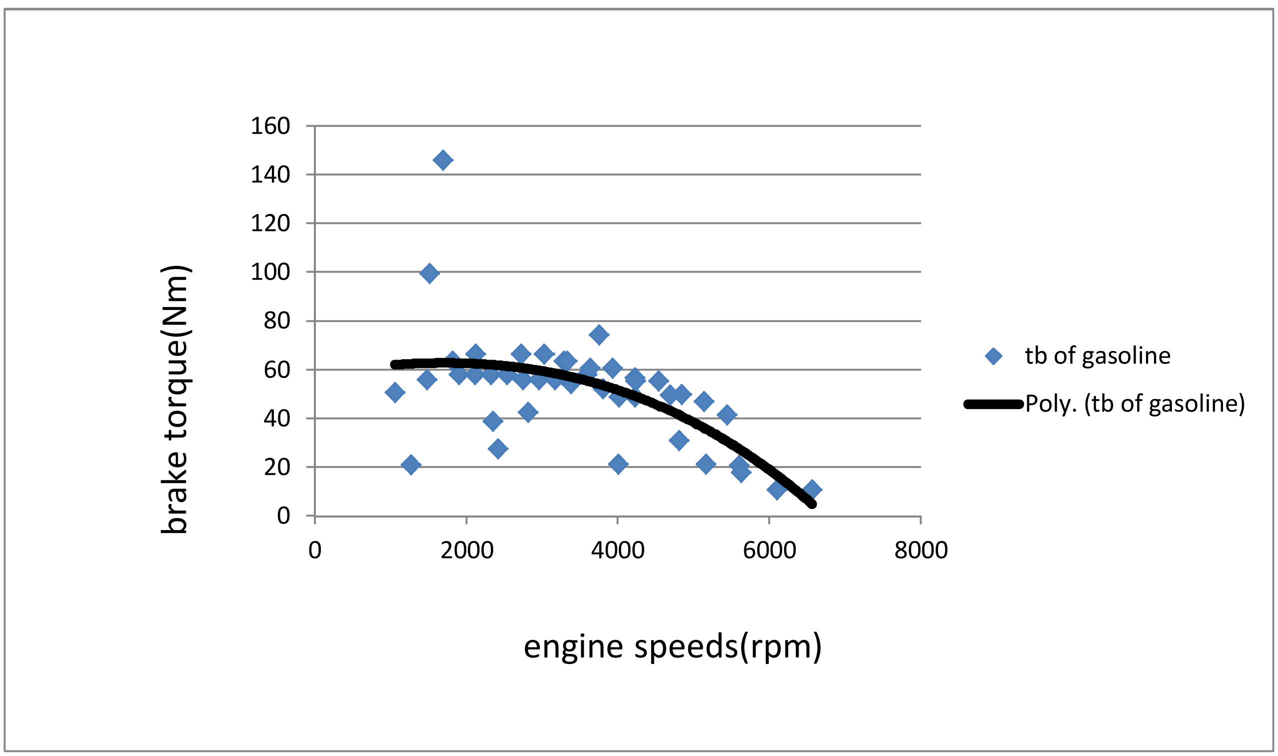


Figure 5.16 Average brake torque when vehicle running with Gasoline fuel curve

Table: 5.13 Brake torque when vehicle running with Ethanol-Gasoline fuel

Vehicle speed	Brake torque (Nm)			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	37.3	106	99.4	181.3
30	20.7	84.9	38.6	174.3
35	32.5	77.8	27.6	167.4
40		56.6	27.6	118.6
45		56.6	27.6	90.7
50		67.2	60.7	57.9
55		26.50	60.7	57.9
60		193.45	60.7	57.9
65		24.8	59.6	57.9
70		24.8	55.2	55.8
75			52.4	55.8
80			27.6	55.8
85			22	54.4
90			19	52.3
95				48.8
100				48.8

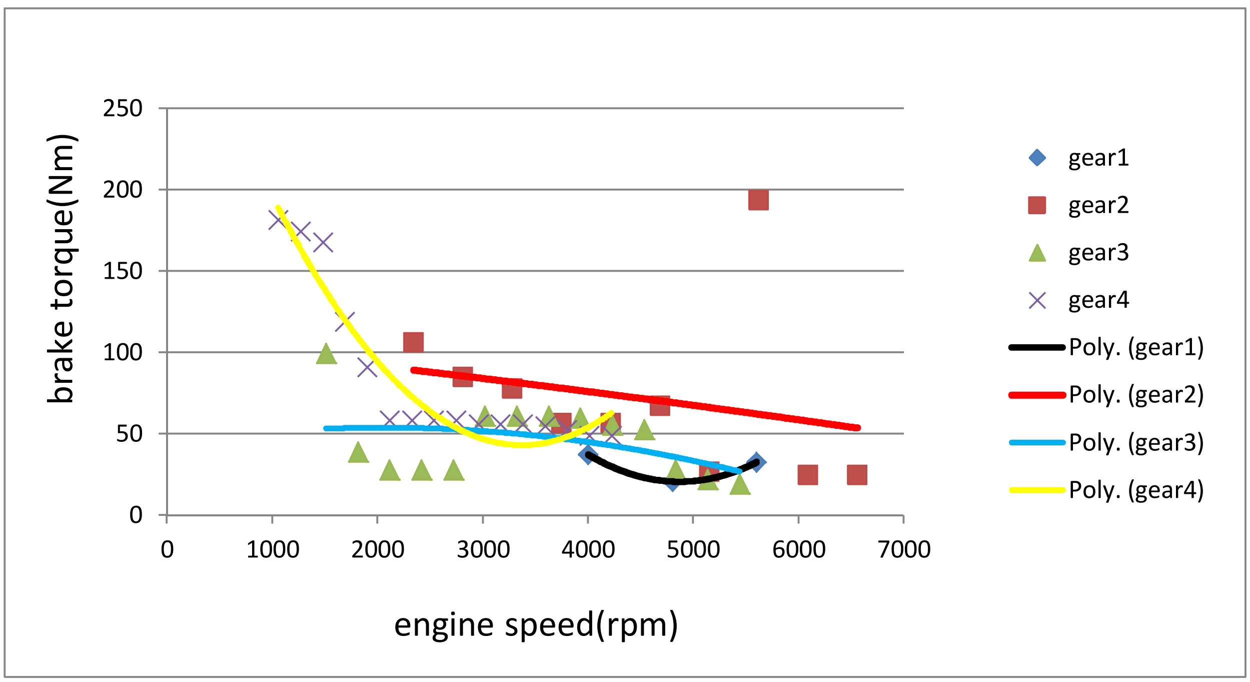


Figure: 5.17 Brake torque

When running on ethanol-gasoline, the maximum brake torque of 80Nm was found at 1055.5rpm.

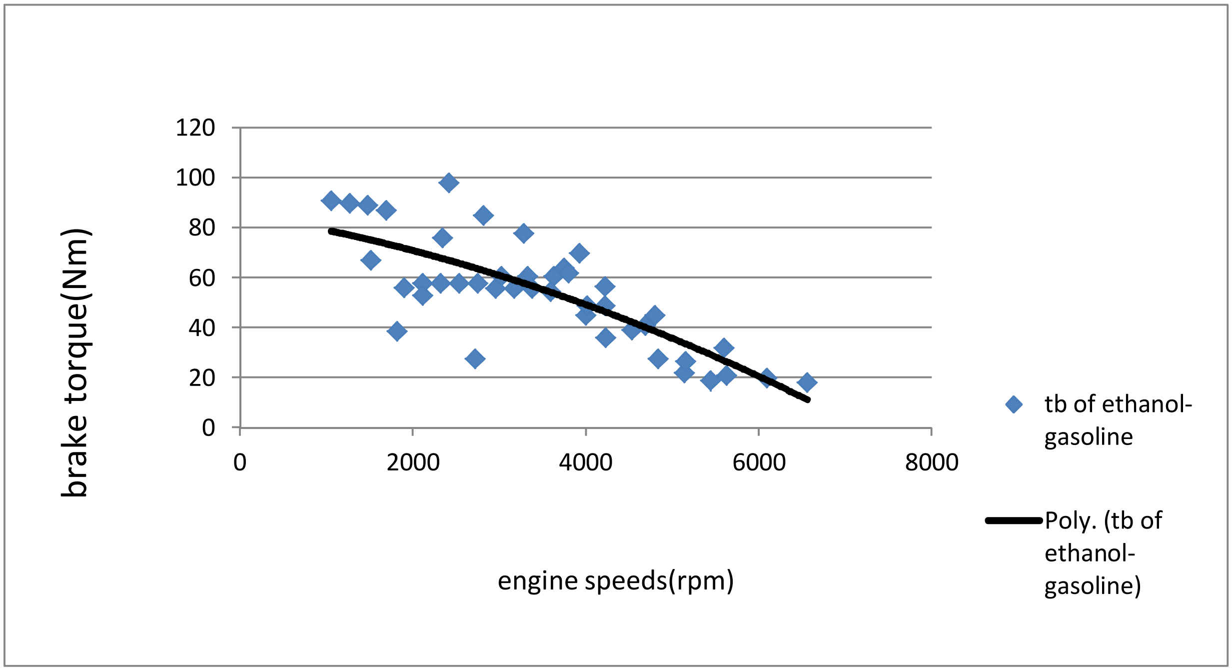


Figure: 5.18 Average brake torque when vehicle running with Ethanol-Gasoline fuel

Table: 5.14 Brake torque when vehicle running with Ethanol-methanol-Gasoline fuel

Vehicle speed	Brake torque (Nm)			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	10.4	56.6	13.8	76.7
30	10.4	84.9	99.4	174.4
35	10.4	74.3	27.7	153.4
40		53	27.7	104.6
45		56.6	63.5	122
50		57.2	63.5	55.8
55		26.5	63.5	55.8
60		8.8	63.5	52.3
65		10.6	60.7	52.30
70		10.6	5.5	62.8
75			55	52.30
80			49.7	52.30
85			27.6	52.30
90			22	52.30
95				48.8
100				48.8

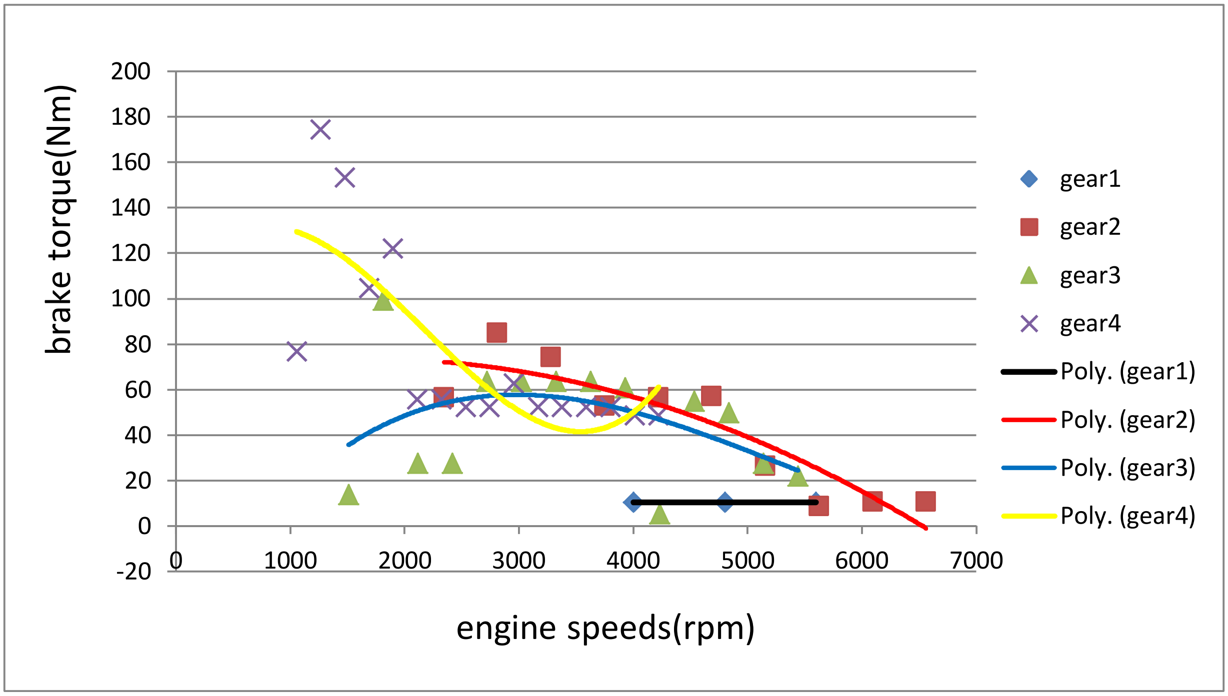


Figure: 5.19 Brake torque

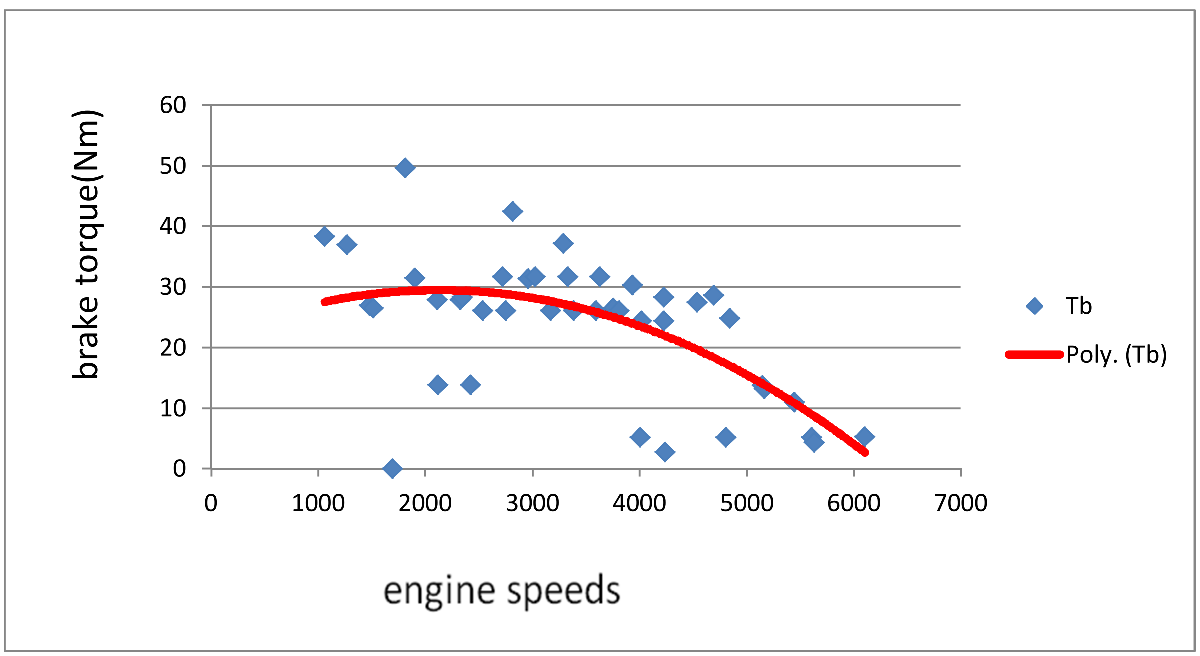


Figure: 5.20 Average brake torque of when vehicle running with Gasoline-Ethanol-methanol fuel carve

The maximum brake torque of Gasoline-Ethanol-methanol at 31.5Nm 1902.9 rpm. The brake torque of gasoline-ethanol-methanol was lower than those of ethanol- gasoline & gasoline blend . Due to the addition of ethanol and methanol the octane number raised. The percentage heat rejected to coolant is more at lower speed. When engine is running at low speed, there is a relatively longer time for heat conduction to engine parts and then to the coolant; this will reduce the heat available for doing work. On the combustion characteristics, the auto-ignition temperature and flash point of ethanol are higher than gasoline, which makes it safer for transportation and storage. The percentage heat rejected to coolant reduces at higher speeds. As engine speed increases there is a relatively shorter time for heat loss and torque reduction due to heat loss will be minimal, thus brake torque rises. One reason for brake torque's drop off at higher speeds is because of reduction in charge filling, i.e.; it becomes more difficult to ingest a full charge of air in to the cylinders. As engine speed increases there is relatively shorter opening duration for the intake valves, the valves close before the cylinder is fully filled with air fuel mixture, consequently brake power starts to fall. The other reason for brake torque reduction at higher speeds is because a considerably more heat is carried by exhaust at higher speeds. As the engine speed increases, the exhaust valves open sooner than they open at lower speed; this will carry away some of the combustion heat and consequently, torque drops as speed increases.

The brake torque results obtained can be summarized briefly as follows:

Ethanol-gasoline has produced more brake torque than gasoline and gasoline-methanol-ethanol blend. When running on methanol-ethanol-gasoline a maximum brake torque is31.5Nm, when running gasoline- ethanol a maximum brake torque is 80 Nm and when running gasoline maximum brake torque is 63.5Nm was found. The least brake torque of 10.60 Nm is also registered when running on gasoline & methanol-ethanol –gasoline is 5.3Nm. The least brake torque of ethanol-gasoline is 20 Nm. The average torque when running on gasoline is 18.5 Nm, for ethanol-gasoline blends 50 Nm and for methanol- ethanol-gasoline blend it is18.4 Nm. On average the brake torque of gasoline-ethanol is higher than the brake torque of gasoline & methanol-ethanol- gasoline. The lesser density of gasoline and the lesser octane number are responsible for gasoline reduced brake torque.

Generally the brake torque curve shows the maximum brake torque of methanol-ethanol-gasoline is lower than gasoline & ethanol-gasoline. When the engine is running from medium to high speed the brake torque of gasoline is slightly higher than ethanol-gasoline & methanol-ethanol-gasoline. When the engine is running at high speed almost the brake torque of gasoline, ethanol-gasoline & methanol-ethanol gasoline graphs drop suddenly.

5.3 Evaluation of brake power[25]

$$Pb = \frac{Pw}{\eta t} \qquad \text{..} \quad (8)$$

Where P_b = brake power P_w = power at wheel η_t= overall transmission efficiency

Table: 5.15 Brake power when vehicle running with Gasoline fuel

Vehicle speed	Brake power in KW			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	15	15	13.75	12.2
30	5	12.5	13.125	12.2
35	12.5	24.7	13.75	7.22
40	12.5	15	12.5	23.3
45		27.5	18.75	11.11
50		16.25	20.6	12.55
55		12.5	22.5	15.63
60		12.125	25	15.66
65		11.5	25	15.55
70		11	25	17.8
75			22.5	18.9
80			15	22.5
85			12.5	21.4
90			11.25	22.2
95				22.2
100				22.2

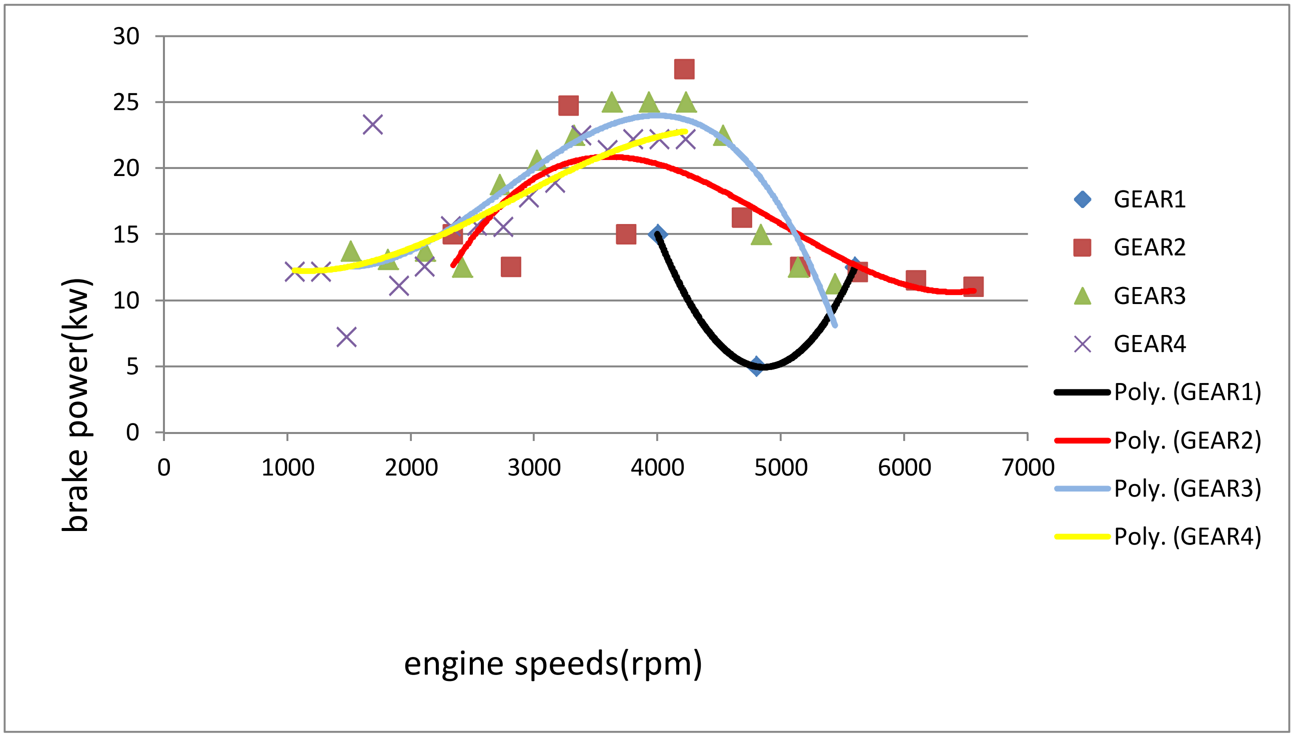


Figure: 5.21 Brake power

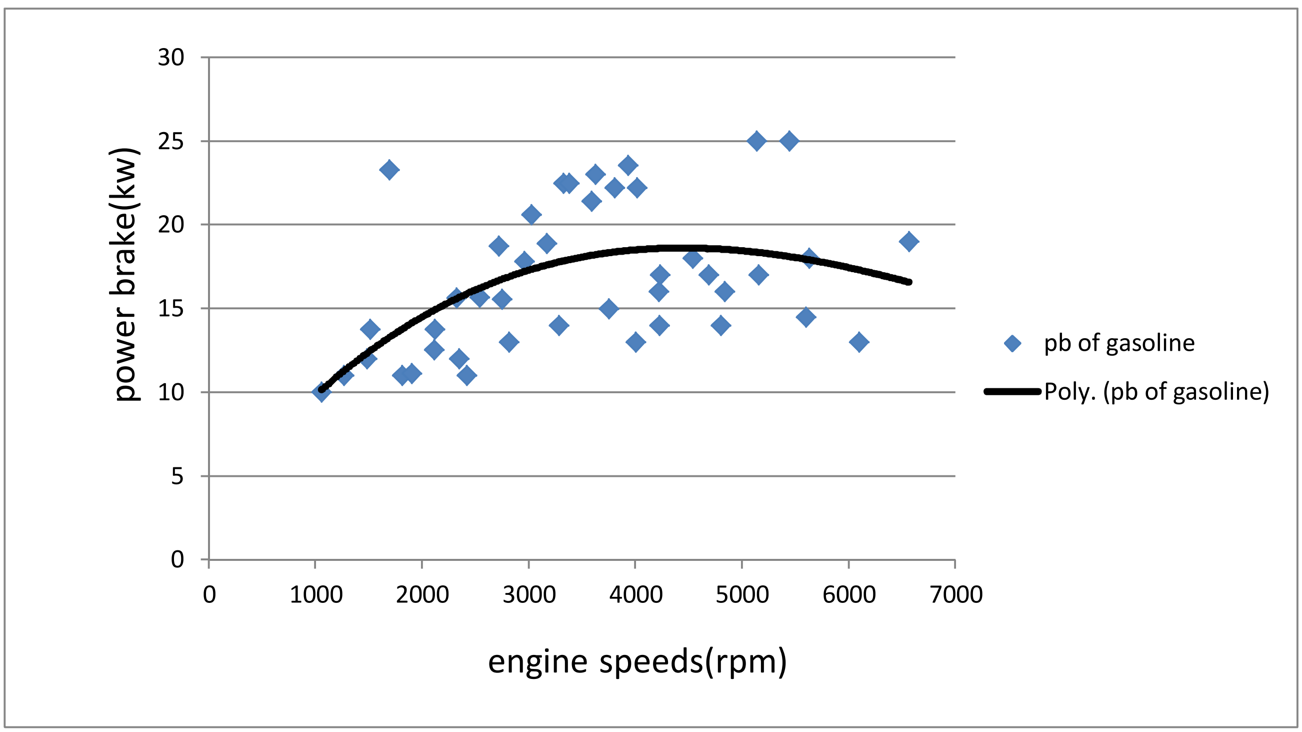


Figure: 5.22 Average brake power when vehicle running with Gasoline fuel

A maximum brake power 18 kW is obtained at 4531.52rpm when running on gasoline

Table: 5.16 Brake power when vehicle running with Ethanol-Gasoline fuel

Vehicle speed	Brake power in kw			
Km/hr	1st gear	2nd gear	3rd Gear	4thGear
25	15	25	10	23.3
30	10	25	12.5	23.3
35	12.5	26.25	10	20
40		22.5	7.5	20
45		22.5	12.5	22.5
50		28.75	22.5	12.22
55		15	23.75	13.33
60		12.5	25	14.44
65		12.125	26.25	15.55
70			25	11.11
75			26.25	17.8
80			25	18.88
85			12.5	20
90			10	21.44
95				21.44
100				21.44

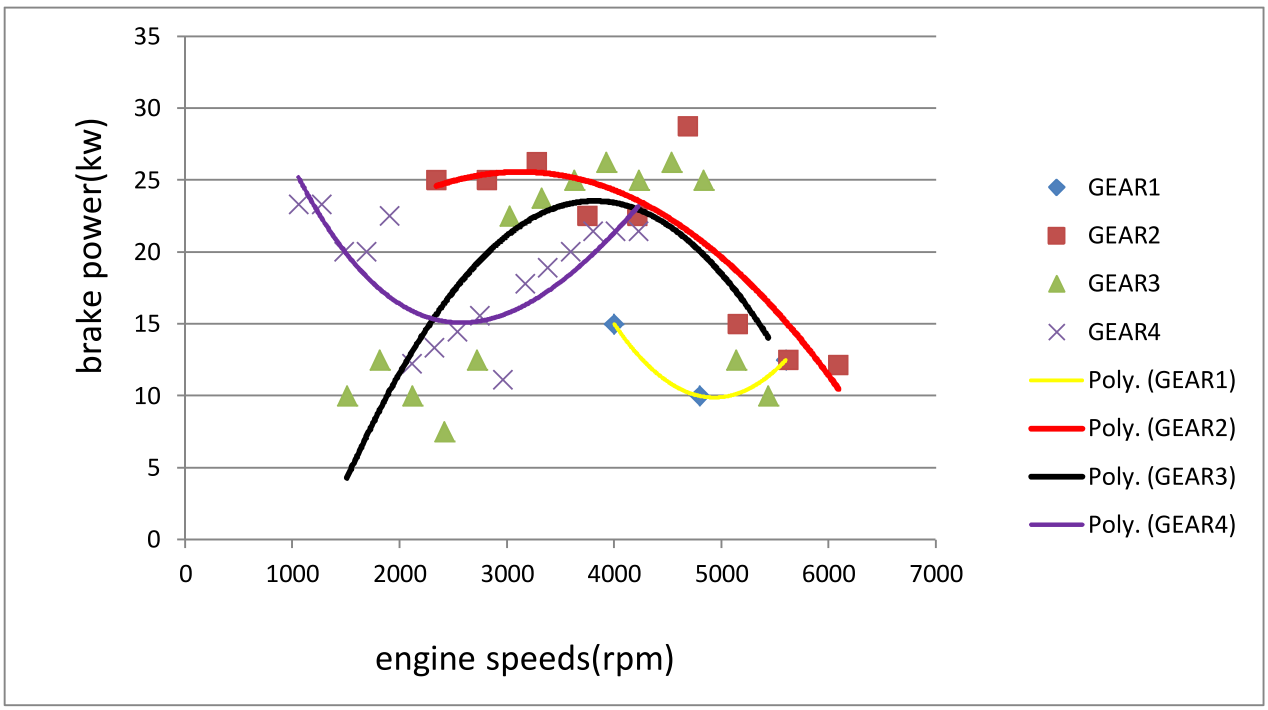


Figure: 5.23 Brake power

A maximum brake power 42 kW is obtained at 5135 rpm when running on Ethanol-gasoline

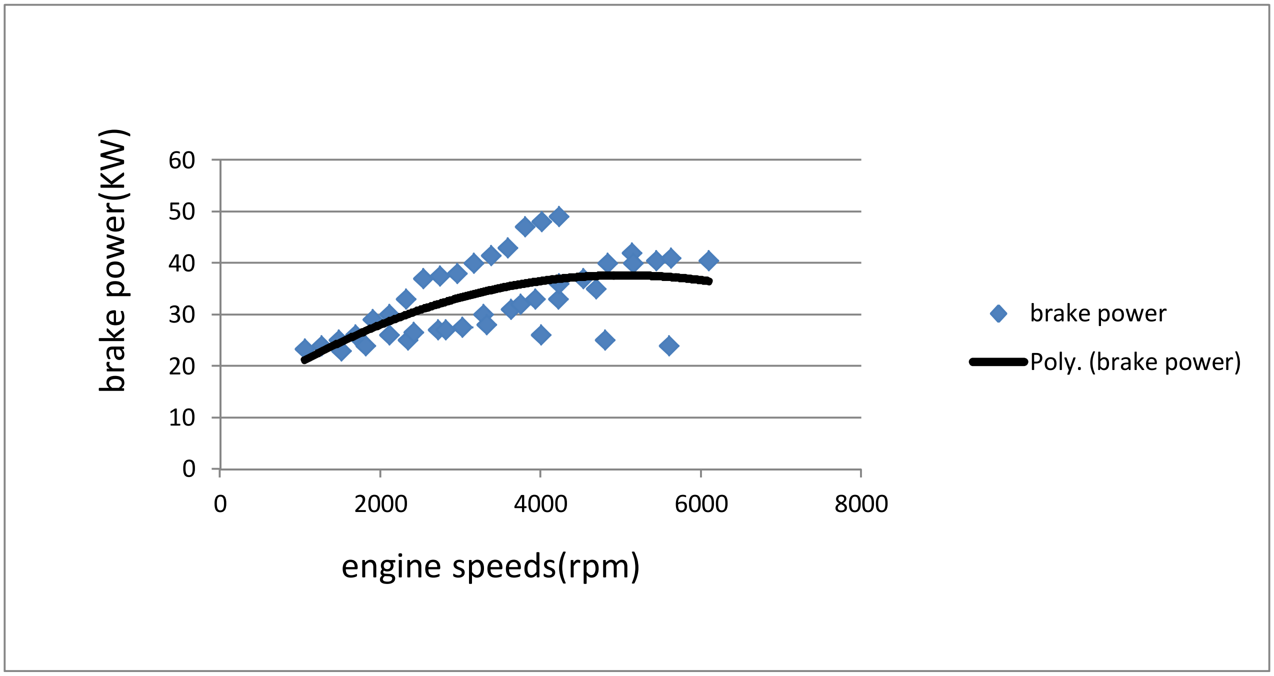


Figure 5.24 Average brake power when vehicle running with Ethanol-Gasoline fuel

Table: 5.17 Brake power when vehicle running with Ethanol-methanol-Gasoline fuel

Vehicle speed	Brake power(kw)			
Km/hr	1st gear	2nd gear	3rd Gear	4thGear
25	15	27.5	10	4.444
30	10	25	20	23.3
35	12.5	25	12.5	22.22
40		22.5	12.5	20
45		30	5	24.4
50		28.75	22.5	12.22
55		15	23.75	13.33
60		12.5	25	14.44
65		12.125	26.25	15.56
70			25	11.11
75			26.25	17.8
80			25	18.9
85			12.5	20
90			10	21.4
95				21.7
100				21.7

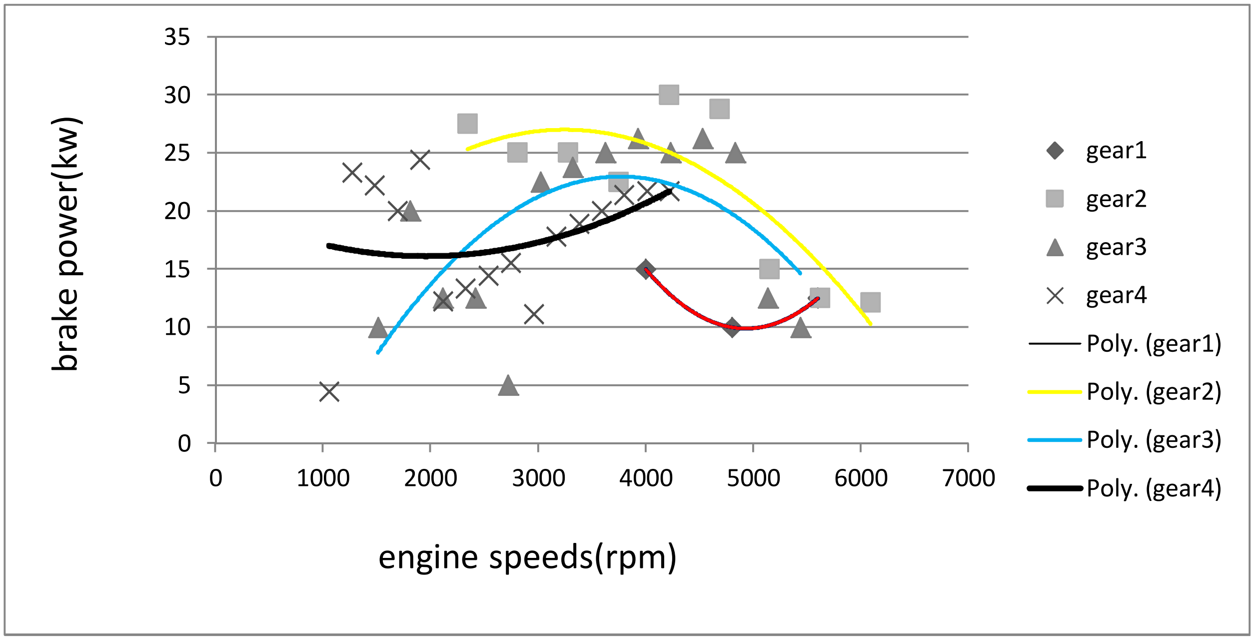


Figure 5.25 Brake power

A maximum brake power 22.5 kW is obtained at 3755 rpm when running on Ethanol-gasoline

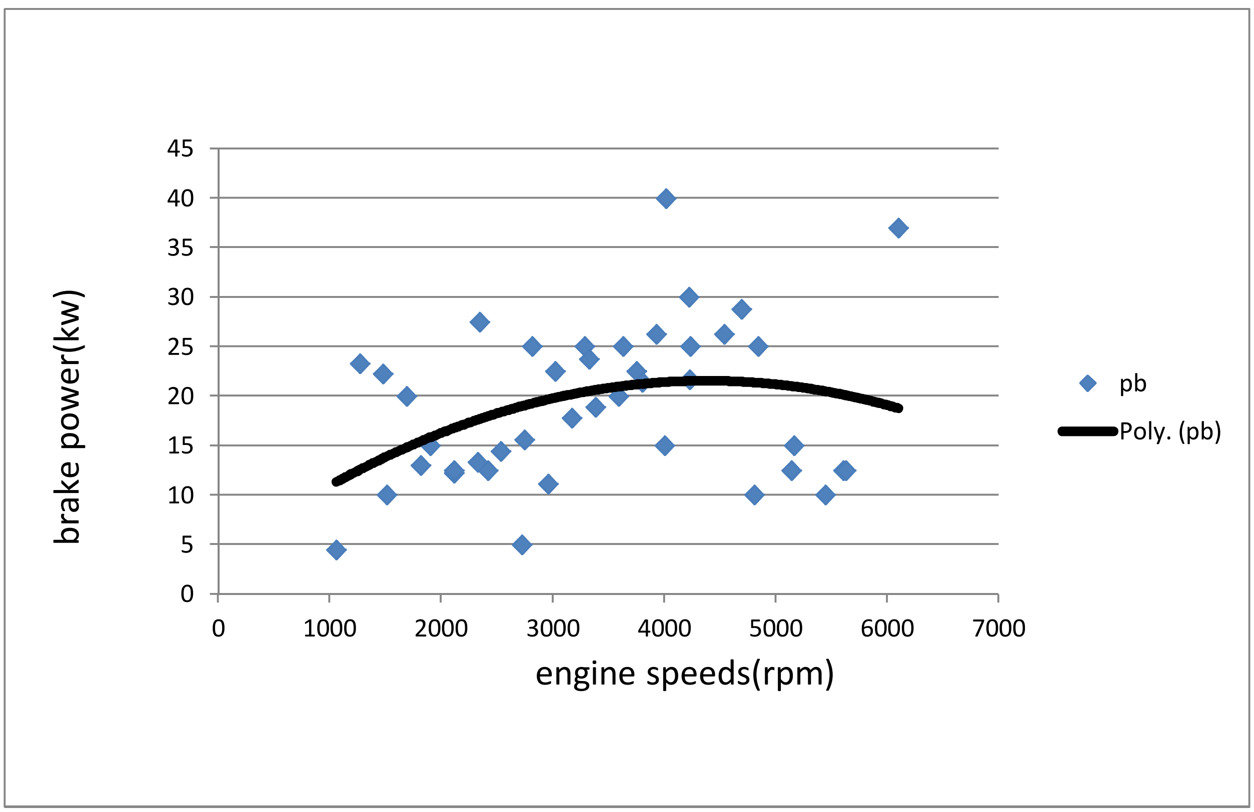


Figure 5.26 Average brake power when vehicle running with Ethanol-methanol-Gasoline fuel

A maximum brake power 22.5 kW is obtained at 3755rpm when running with methanol-ethanol- gasoline blend fuel. Brake power comparison is Gasoline, Ethanol-Gasoline and Methanol-Ethanol-Gasoline versus Engine speed. At low engine speed the friction power is relatively low and therefore the brake power increases with speed. As engine speed increases, however, the friction power starts to increase at continuously greater rate and therefore brake power reaches a peak and starts reducing. As engine speeds above the usual operating range, friction power increases very rapidly. Another reason for the falling off brake power at high speed is less complete filling of the cylinder consequent on greater reduction of pressure. The fact that valve timing is designed for moderately high speed will indirectly reduce the brake power at low speeds and also due to the dependence of the engine power on engine speed. When gasoline fuel and E10 blend is used, results indicated that 2%methanol 10% ethanol blend with 88% gasoline increases the engine power output due to increase in octane number when ethanol and methanol is added. At minimum engine speed it may be seen that due to better combustion conditions and lower temperature in the intake manifold the brake power increases. Also with an increase in ethanol percentage, the density of the blend and the engine volumetric efficiency increases and this cause an increase in power

The brake power results obtained can be summarized as follows:

The average brake power for gasoline operation is 14 kW, for ethanol-gasoline 32.65 kW and for methanol-ethanol-gasoline 18.75 kW. When average values of brake power are compared, gasoline is lower than gasoline-ethanol& methanol- ethanol-gasoline. However; at lower vehicle speed the average brake power of ethanol-gasoline is greater than gasoline.

5.4 Evaluation of brake specific fuel consumption

In engine tests, the fuel consumption is measured as a flow rate; mass flow per unit time (ṁf). A more useful parameter is the specific fuel consumption (sfc) the fuel flow rate per unit power output. It measures how efficiently an engine is using the fuel supplied to produce work.

Specific fuel consumption (sfc) $\frac{massflowrate(\dot{m}f)}{power(p)}$ ………………………………………(9)

Brake specific fuel consumption (bsfc) $\frac{massflowrate(\dot{m}f)}{brakepower(bp)}$ ……………… ………… …... (10)

Measurement of gasoline consumption was made by recording the time taken for the consumption of ten grams of gasoline. The mass flow per unit time, ṁf of gasoline consumed is calculated by dividing ten grams to the time taken for its consumption. The value thus obtained at each test speed and running gear is shown table 5.18, 5.19 and 20 [25]

Table: 5.18 Mass flow rate when vehicle running with Gasoline fuel

Vehicle speed	ṁf in gm/sec			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	2.5	2.5	2	0.9
30	2.4	2.1	2.2	0.85
35	3.24	2.19	2.83	1.00
40		2.8	3	1.3
45		2.75	2.83	1.3
50		2.64	2.57	1.5
55		2.45	2.9	1.75
60		2.64	2.7	1.8
65		2.68	2.9	1.87
70		2.72	2.73	2.44
75			2.86	2.11
80			3.00	2.15
85			3.00	2.36
90			3.7	2.33
95				2.53
100				2.72

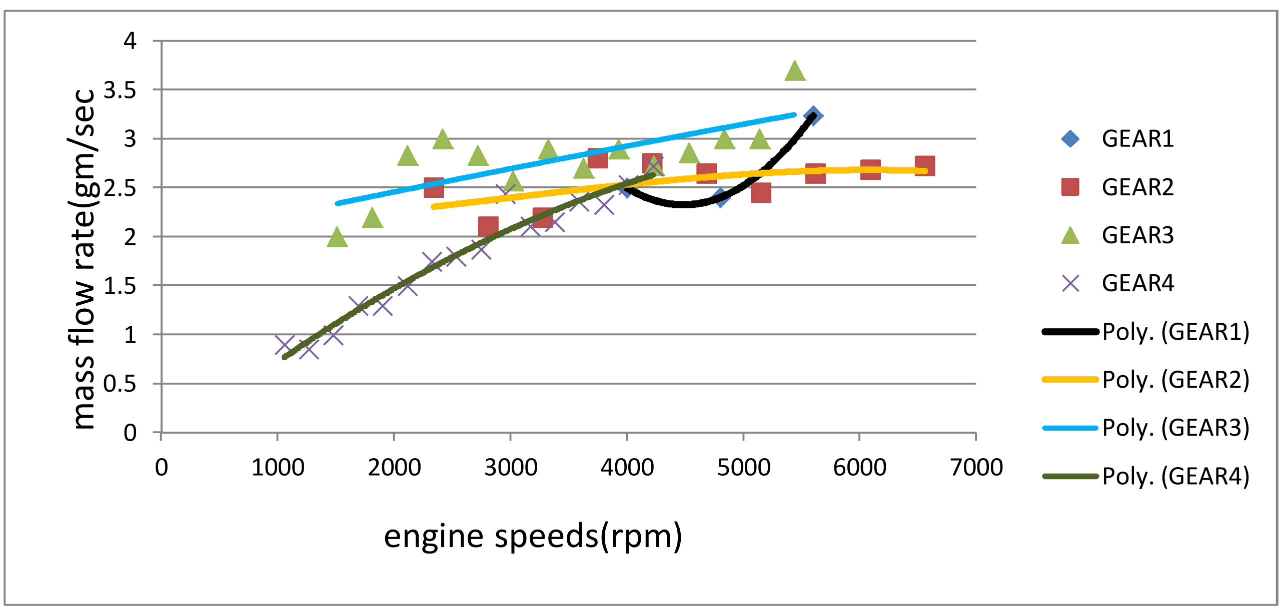


Figure: 5.27 Mass flow rate

Table: 5.19 Mass flow rate when vehicle running with Ethanol-Gasoline fuel

Vehicle speed	$\dot{m}f$ in gm/sec			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	2	2	2.5	2
30	2.56	1.95	2.29	1.83
35	2.53	2.16	2.59	1.6
40		2.33	2.22	1.17
45		2.64	2.44	1.34
50		2.87	2.54	1.61
55		3.07	2.73	2
60		3.19	2.68	2.05
65		2.58	2.78	2.54
70		2.93	2.99	2.14
75			2.85	3.28
80			2.57	2.17
85			3.05	3
90			3	2.7
95				2.66
100				2.3

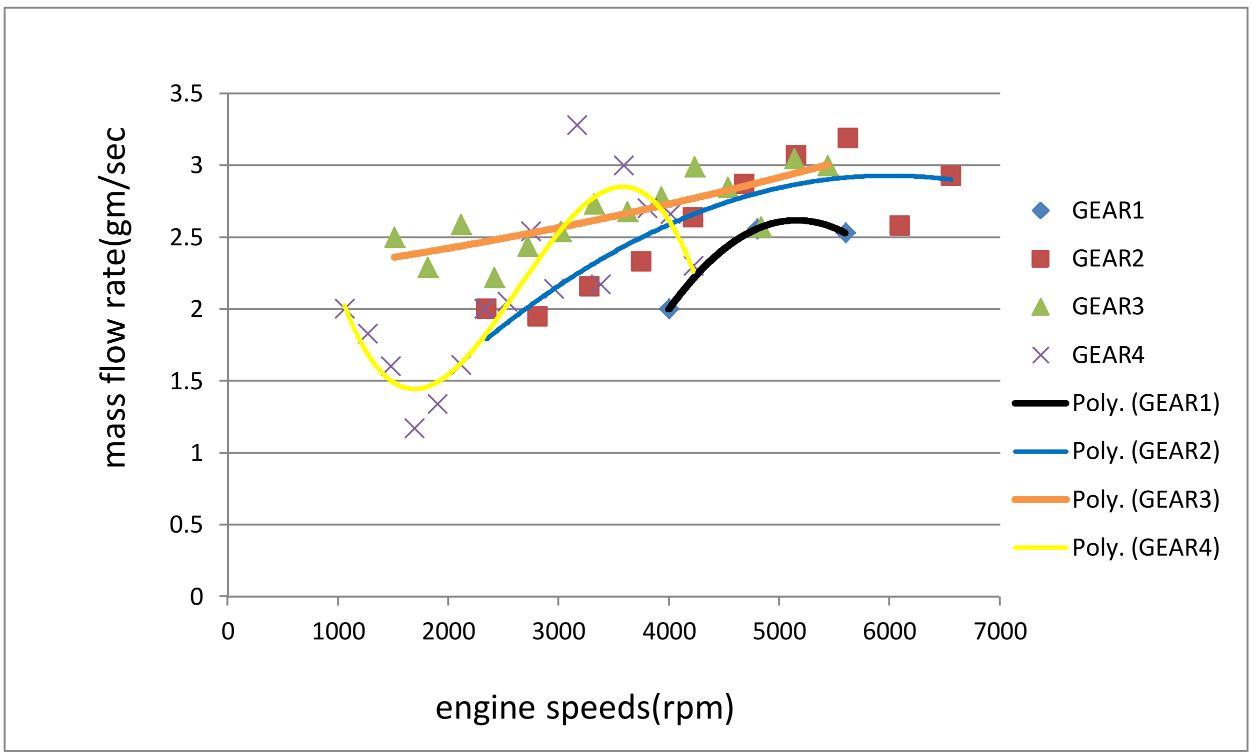


Figure: 5.28 Mass flow rate

Table: 5.20 Mass flow rate when vehicle running with Ethanol-methanol-Gasoline fuel

Vehicle speed	ṁf in gm/sec			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	3	1.85	1.07	0.79
30	3.05	1.90	1.24	0.9
35	3.27	2.27	1.49	1.1
40		2.22	1.75	1.26
45		2.84	2.19	1.55
50		3.29	2.12	1.58
55		2.38	2.07	2.25
60		2.82	2.88	2.22
65		2.89	2.61	2.38
70		2.72	2.96	2.93
75			3.1	3
80			3.19	2.57
85			2.2	2.77
90			2.72	2.8
95				2.37
100				3

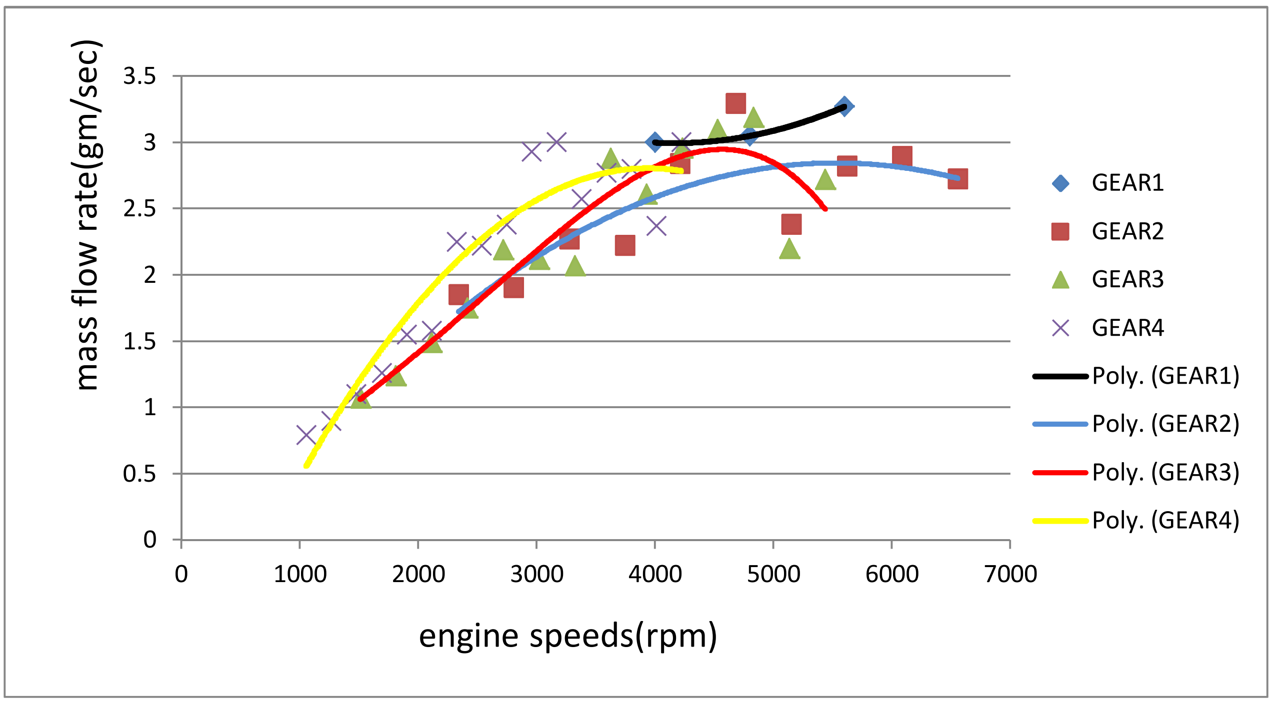


Figure: 5.29 Mass flow rate

The brake specific fuel consumption (bsfc) was calculated in order to understand the variations of fuel consumption in the test engine using different fuels such as gasoline, ethanol-gasoline

&methanol-ethanol-gasoline fuels blend. Once the mass flow rate of the fuel is determined, the brake specific fuel consumption can be calculated using the equation (11) [25].

$$(bsfc) = \frac{\dot{m}f\left(\frac{gm}{sec}\right)X3\ 6\ 00}{pb}\left(\frac{gm}{kWhr}\right) \quad \text{...}(11)$$

Scale 1:75

Table: 5.21 bsfc when vehicle running with Gasoline fuel

Vehicle speed	Bsf in gms/kWhr			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	6.9	6.9	6.98	6.0
30	7.48	7.48	5.75	3.3
35	5.5	5.5	9.88	6.6
40		8.96	11.52	2.7
45		4.8	7.245	5.6
50		4.3	5.98	5.7
55		7.2	6.186	5.4
60		6.8	5.184	5.0
65		6.0	5.568	4.7
70		7.0	5.24	4.6
75			6.10	4.5
80			9.6	4.0
85			11.52	3.7
90			5.746	5.0
95				5.5
100				5.9

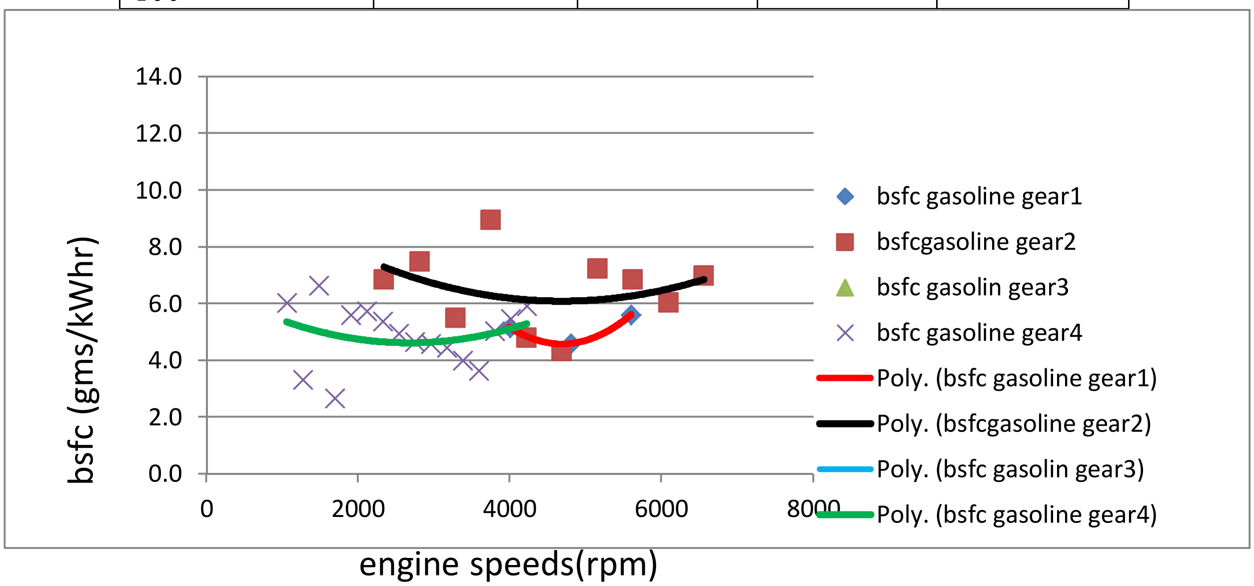


Figure: 5.30 bsfc

The least bsfc of 250 gm/kWhr is found at 1267 rpm & the maximum bsfc of 1184 gm/kWhr at 5438 rpm when the vehicle running with gasoline fuel.

Table: 5.22 bsfc when vehicle running with Ethanol-Gasoline fuel

Vehicle speed	Bsfc in gms/kWhr			
Km/hr	1st gear	2nd gear	3rd Gear	4th Gear
25	480	531	613	762
30	467	465	543	423
35	523	296	412	288
40		372.8	542	210.6
45		422.4	531	214.4
50		359.4	406.4	394.8
55		672	413.8	540
60		712	452	511
65		413	381	588
70		546	430.56	411
75			390.86	312
80			433	413.8
85			423	540
90			412	453.4
95				446.6
100				386.2

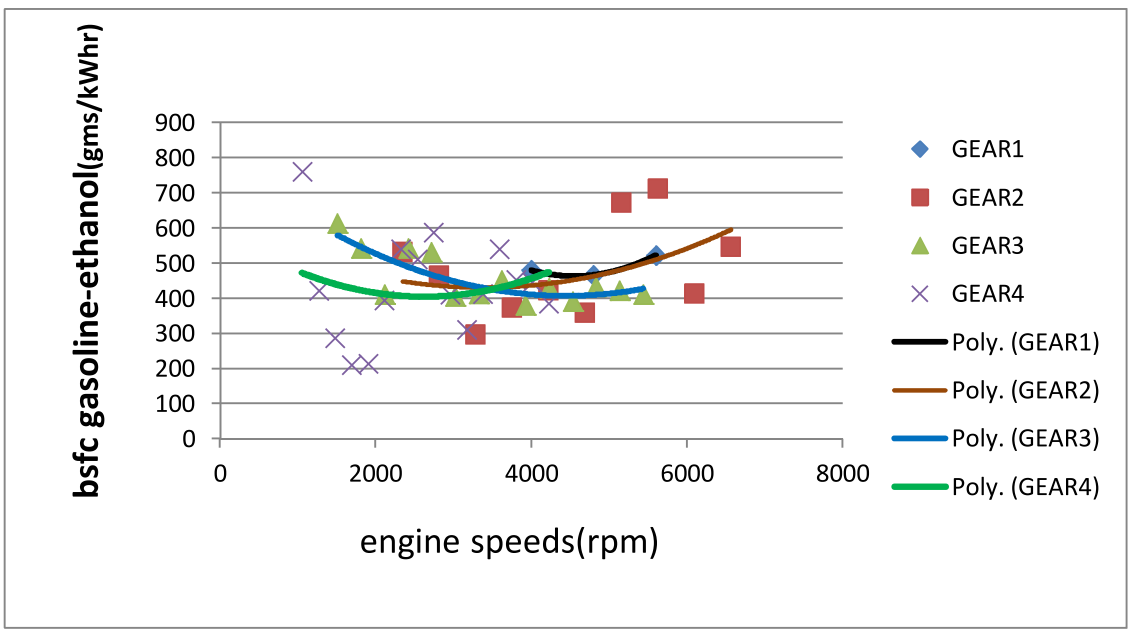


Figure: 5.3.1 bsfc

The least bsfc of 210.6gm/kWhr is found at 1689 rpm & the maximumbsfc of 1065.6 gm/kWhr at 2417 rpm when the vehicle running with ethanol & gasoline blend fuel

Scale 1:75

Table: 5.23 bsfc when vehicle running with Ethanol-methanol-Gasoline fuel

Vehicle speed	Bsfc in gms/kWhr			
Km/hr	1st gear	2nd gear	3rd Gear	4thGear
25	9.6	7.21	5.14	10.1
30	7.08	5.75	2.98	5.5
35	8.57	4.36	5.72	5.3
40		4.74	6.72	5.0
45		4.54	21.02	5.7
50		5.49	4.52	6.2
55		7.62	4.18	8.1
60		7.08	5.53	7.4
65		11.16	4.77	7.3
70		5.23	5.68	5.5
75			5.67	4.7
80			6.13	5.3
85			8.45	5.2
90			13.06	6.3
95				6.2
100				6.6

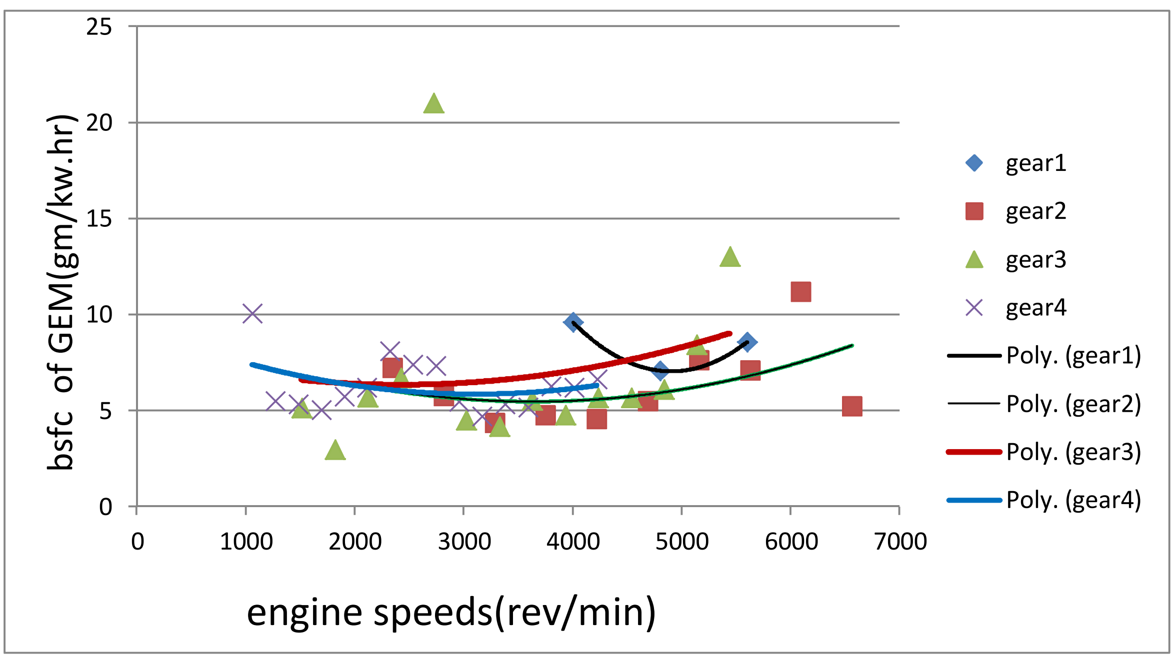


Figure: 5.32 Brake specific fuel consumption curves

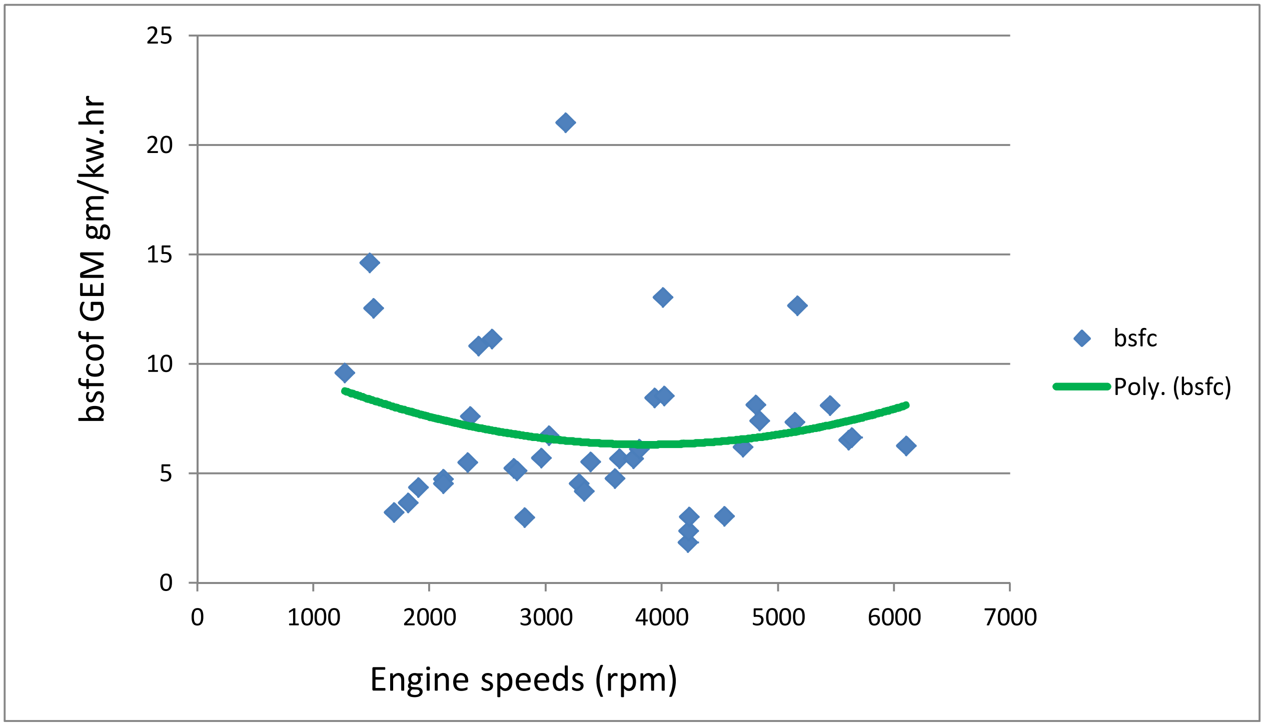


Figure 5.33 Average brake specific fuel consumption curve

The least bsfc of 139 gm/kWhr is found at 1267 rpm & the maximum bsfc of 1576.8 m/kWhr at 2719 rpm when the vehicle running with ethanol 10% v%, 2v% methanol & gasoline 88v% blend fuel.bsfc (Gasoline, Ethanol-Gasoline and methanol-Ethanol-Gasoline) versus engine speed.

Average fuel consumption when vehicle running with methanol-ethanol-gasoline fuel

The average bsfc of ethanol-gasoline (564gm/kWhr), gasoline (663gm/kWhr) & methanol-ethanol-gasoline (595gm/kWhr). Therefore, the bsfc average of gasoline is higher than gasoline – ethanol & methanol-ethanol-gasoline. Also, difference exists between the bsfc using pure gasoline, ethanol-gasoline and methanol-ethanol-gasoline blended fuels. Due to oxygen in ethanol& methanol composition the combustion process improves in the engine cylinders. However, specific fuel consumption slightly increases mostly at middle range speed when compared to gasoline.

Scale P_b= 1:1, T_b = 1:2 and bsfc = 1:75

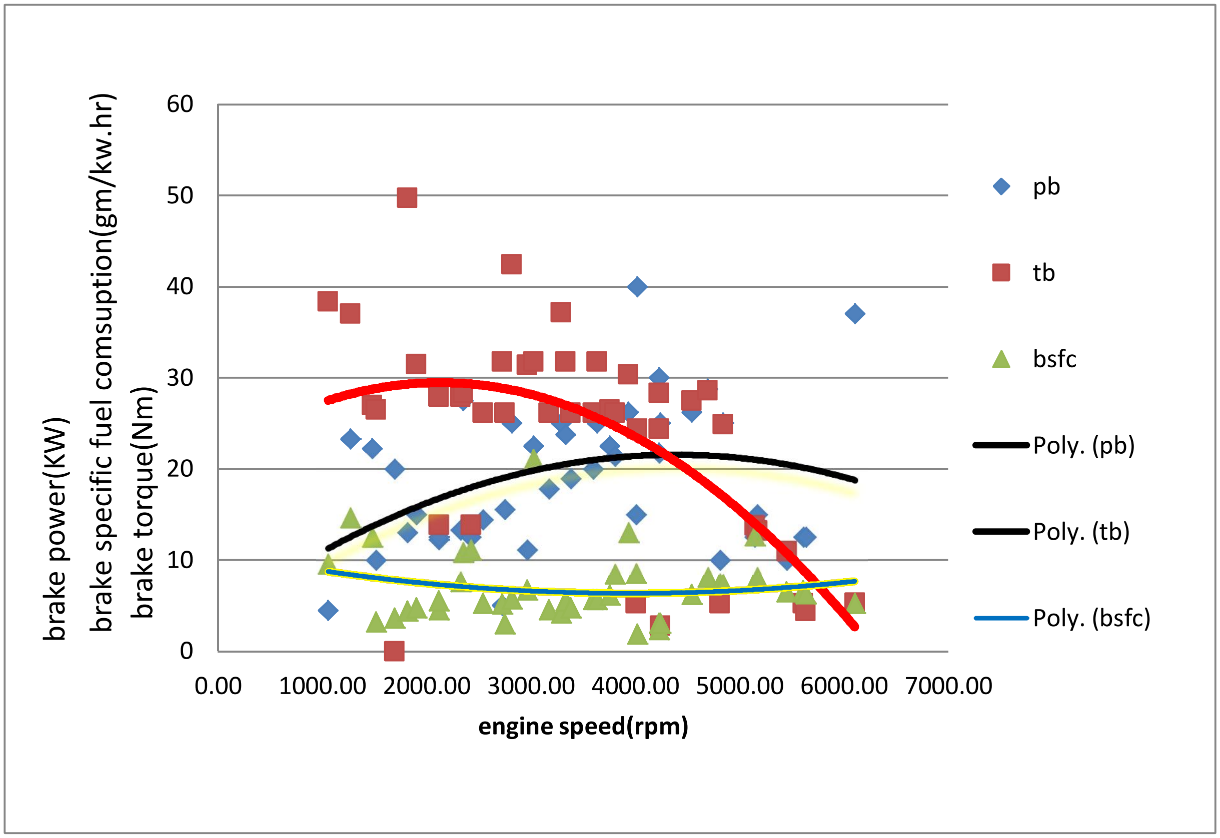


Figure: 5.34 Performance curve

Running cost

The mass of gasoline, ethanol-gasoline and methanol-ethanol-gasoline consumed to cover one kilometer is computed from the data collected (Table 5.24, 5.25 and 5.26) respectively by the driving the fuel consumed (gm/hr) by the vehicle speed (km/hr) for each gear. Once the fuel consumed per kilometer is known, the fuel cost per kilometer can be calculated using the current market price. Currently one liter gasoline, ethanol and methanol price is 18, 13.48 and 9.00 birr respectively. One litter of gasoline is equivalent to 726.22 gm. One liter of ethanol-gasoline & methanol -ethanol-gasoline in gram can be calculated as follows.

The measured value of 880 ml gasoline in gram is 581. Since 880 ml gasoline by volume found in the one liter of methanol-ethanol-gasoline blend the cost of 880 ml of gasoline is calculated from the cost of one liter gasoline which is 18. Therefore the cost of 880 ml gasoline is 10.46birr. The amount of ethanol in one litter gasoline-methanol-ethanol blend is 100 ml by volume. The measured value of 100 ml of ethanol in gram is 77.79. The cost of 100 ml ethanol is calculated from the cost of one liter ethanol which is 13.48 birr. Therefore the cost of 100 ml of ethanol is 1.348birr.

When we measure 20 ml methanol on balance the measured value of methanol in gram is 15.56. In one liter gasoline-ethanol-methanol blend the amount of methanol by volume is 0.02 %. The cost of 0.02 % methanol in the blend is calculated from the cost of one liter of methanol, which is 9 birr. Therefore the cost of 0.02 % methanol is 0.18 birr.

The cost of 10% ethanol and 88 % gasoline blend can be calculated from the cost of one liter ethanol and one liter gasoline. Accordingly cost of one liter ethanol-gasoline blend (10% ethanol and 88% gasoline) is 11.808 birr. To get fuel cost per gram of ethanol-gasoline blend, dividing one liter fuel cost for one liter mass (11.808/581) indicates that one gram costs is 0.02 birr. Also to get the average cost per kilometer, multiplying one gram cost by the average gm/km for each gear. The sum of cost of 20 ml methanol, 100 ml ethanol and 880 ml gasoline is 11.988 birr. Therefore the cost of one liter of methanol-ethanol-gasoline blend is 11.988birr.

The fuel cost per gram of methanol-ethanol-gasoline can be calculated by dividing one liter cost for one liter mass (11.988 birr/674.34) of methanol-ethanol-gasoline blend. Therefore one gram cost of methanol-ethanol-gasoline is 0.0178 birr. To get the average cost per kilometer, multiplying one gram cost (0.0178 birr) by the average gm/km for each gear. The average value cost per kilo meter for each fuel is presented in the table below

Gasoline blend running cost

Table: 5.24 Gasoline running cost

Vehicle speed km/hr	Gasoline consumption in gm/km and Running cost birr/km					
	1st Gear	2nd Gear	3rd Gear	4th gear	Average gm/km	Running cost birr/km
25	360	360	288	129.6	309	7.658
30	288	240	264	102	223.5	5.5396
35	333	225	291	103	238	5.899
40		252	270	117	213	5.279
45		220	226.4	104	183.5	4.5482
50		190	185	108	161	3.99
55		160	190	115	155	3.8418
60		158.4	162	108	142.8	3.5394
65		148	161	104	137.6	3.4105
70		140	140.5	125.5	135.3	3.3535
75			137.3	101.3	119.3	2.9569
80			135	96.75	115.9	2.8726
85			127	100	113.5	2.81319
90			148	93.2	120.6	2.989
95				96	96	2.3794
100				98	98	2.4290
Average					**160.125**	**3.9686**

From the table above since the minimum gasoline fuel cost per kilometer is 2.3794 birr; it is advisable to run the vehicle for a long period of time at 95 Km/h

Gasoline-ethanol blend running cost

Table: 5.25 Gasoline-Ethanol Running cost

Vehicle speed km/hr	Gasoline-ethanol consumption in gm/km and Running cost birr/km					
	1st gear	2nd Gear	3rd Gear	4th gear	Average gm/km	Running cost birr/km
25	288	288	360	288	306	6.219
30	307	234	275	192	252	5.1215
35	260	222	266.4	165	228	4.6337
40		210	200	105	171.7	3.4692
45		211	195	107	171	3.4753
50		207	183	116	168.7	3.42825
55		201	179	131	170.33	3.4617
60		191	161	123	158.33	3.2178
65		143	154	141	146	2.9672
70		151	154	110	138.33	2.81136
75			137	157	147	2.9875
80			116	98	107	2.1746
85			137	127	132	2.6827
90			120	108	114	2.3168
95				100.8	100.8	2.0486
100				82.8	82.8	1.6827
Average					**162.12**	**3.2936**

As one can observed from the table 5.26 the minimum running cost of ethanol-gasoline blend per kilometer is 1.6827 birr. Therefore it is advantageous running the vehicle for long period of time at 100km/hr.

Gasoline-ethanol-methanol blend running cost

Table: 5.26 Gasoline-ethanol-methanol running cost

Vehicle speed km/hr	Gasoline-ethanol-methanol consumption in gm/km Running cost birr/km					
	1st gear	2nd Gear	3rd Gear	4th gear	Average gm/km	Running cost birr/km
25	432	266	154	114	241.5	4.293
30	366	225	149	108	212	3.76
35	336	233.5	153	113	208.8	3.7118
40		200	157.5	113	156.8	2.7874
45		227	175	124.1	175.36	3.1174
50		237	81	114	144	2.5599
55		156	235.5	147	179.5	3.1909
60		169	173	133	158.3	2.814
65		160	145	132	145.7	2.59
70		140	152	151	147.7	2.6256
75			149	144	146.5	2.604
80			144	116	130	2.311
85			93	117	105	1.866
90			109	112	110.5	1.9643
95				90	90	1.5999
100				108	108	1.9199
Average					**153.73**	**2.7322**

From the table 5.27 since the minimum gasoline-ethanol-methanol blend fuel cost per kilometer is 1.5999 birr; it is advantageous to run the vehicle for a long period of time at 95 Km/hr.

CHAPTER SIX

6. CONCLUSION AND RECOMMANDATIONS

6.1 Conclusion

The main aim of the study was to test the performance of gasoline vehicle with gasoline - ethanol - methanol emulsion as a fuel making necessary modification in the fuel system.

6.1.1 Based on the brake torque characteristics

Ethanol-gasoline has produced more brake torque than gasoline & ethanol-Methanol-gasoline blend. When running on methanol-ethanol-gasoline a maximum brake torque of 31.5 Nm, when running on gasoline-ethanol maximum brake torque of 80 Nm and when running on gasoline maximum brake torque of 63.5 Nm. was found. The brake torque of 10.6 Nm is also registered when running on gasoline & the least brake torque of 5.3Nm methanol-ethanol –gasoline blends. The least brake torque of ethanol-gasoline is 20 Nm. The average torque when running on gasoline is 37.05 Nm, for methanol-ethanol-gasoline blend it is 18.4 Nm and for ethanol-gasoline blends 50 Nm. On average the brake torque of ethanol- gasoline is slightly higher than the brake torque of gasoline & methanol-ethanol-gasoline.

Based on the torque performance characteristics, it can be concluded that methanol-ethanol-gasoline performs nearly as gasoline, if the vehicle is driven on 3rd gears between the speed of 25 and 30 km/hr. Therefore, methanol-ethanol-gasoline fuel system is better to be used on vehicles which, most of their running time, stay in this speed range. For example, mostly for those vehicles which are driven in the proximity of 25- 30 km/hr, especially when the vehicle is driven in the cities, methanol-ethanol-gasoline is a better alternative to be used on vehicles.

6.1.2 Based on the brake power characteristics

Based on the brake power performance characteristics, it can be seen that methanol-ethanol-gasoline is a nice choice for vehicle that is mostly driven within city speed limits. Vehicles that such as taxis, school transport vehicles, automobiles operating in town and others which are mostly driven at speeds in the vicinity of 45-50 km/hr are better fuelled with methanol-ethanol-gasoline, also for high transport vehicle such as minibus for those mostly driven with the third gear 60-80 km/hr. If such vehicles are converted to run on methanol-ethanol-gasoline blend the performance will be good when compared to ethanol-gasoline & gasoline fuels.

6.1.3 Based on the brake specific fuel consumption characteristics

The average bsfc of ethanol-gasoline (555gm/kWhr), gasoline (650.45gm/kWhr) & methanol-ethanol-gasoline (523.8gm/kWhr). Therefore, the average bsfc of gasoline is higher than ethanol -gasoline & methanol-ethanol-gasoline. Also, difference exists between the bsfc using pure gasoline, ethanol-gasoline and methanol-ethanol-gasoline blended fuels. The brake specific fuel consumption (bsfc) results show that the performance of methanol-ethanol-gasoline is better than gasoline & ethanol-gasoline. From the bsfc result of the experiment methanol-ethanol-gasoline is a better alternative solution to drive vehicles operating in towns.

6.1.4 Based on the running cost

The research has shown that based on the current prices gasoline is 3.9686 birr/km, ethanol-gasoline 3.2936birr/km and gasoline-ethanol-methanol is 2.7322birr/km; So that, running on methanol-ethanol-gasoline is cheaper than running on other two (gasoline and ethanol-gasoline blend).

6.2 Recommendations

If further research is made on methanol-ethanol–gasoline depending on gasoline vehicle's need, we recommend that the researcher should concentrate on different % of methanol-ethanol–gasoline fuel blends which may have a better performance and cost effective.

The we also recommend that the government should emphasize on 2v% methanol , 10v% ethanol and 88v% gasoline blend, because there is a moderate torque, power output and good bsfc when compared with gasoline and ethanol-gasoline blend. Since bsfc of methanol-ethanol-gasoline is lower than gasoline and ethanol-gasoline, indirectly there is a cost reduction on the fuel cost for those vehicle use methanol-ethanol-gasoline blend fuel compared to gasoline.

6.3 Educational Implication

The objective of the national TVET strategy is to create a competent, innovative adaptable work force in Ethiopia contributing to poverty reduction and social & economic development through facilitating demand driven. High quality technical and vocational education and training, relevant to all sectors of the economy, at all levels and to all people in need of skills development and transferring new technologies. (National TVET strategy MOE, 2006).

Since the industries are the stakeholders of the TVET institutions the progress and drop of industry has an impact on the outcome based training. Intensification of the industries and TVET linkage is very important to provide quality and outcome based training. If industries have equipped with enough machinery and equipment, the training program will be easy and efficient. Through industrial training the enterprise can also develop ownership of the TVET system.

Technical and vocational skill is vital to economic development because it is needed for industrial productivity and profitability, as well as national productivity. Without the necessary technical skills, industry and national growth can be seriously hobbled. Technical and vocational education is of great relevance to the technological and economic status of the nation, such as:-

- Technological advance and progression, which naturally lead to economic release and independence
- Appropriate development and proper positioning of the technological and economic power of a nation through appropriate human resource development
- Effective mobility of labor through training and re-training
- Effective handling the issue of transfer of technology and its attendant problems
- Reduction of over dependence on imported product and conservation of the resources that could have been spent in engaging the services of foreign experts

This project is valuable for our country in minimizing a certain amount of gasoline fuel imported and reduces the cost of fuel. Since ethanol is produced domestically, its cost is relatively low. Currently one liter cost of gasoline is 18 birr, but the cost of one liter ethanol is 13.48 and methanol is 9 birr. Generally in this project 2% methanol 10% ethanol and 88% gasoline blend fuel is used. The existence of 10% ethanol and 2% methanol in the blend reduce the overall cost of the fuel. This project also summarizing the major courses taken during the master's program, provide the chance to use some special machines, equipment and tools and assuring the rightness of educational policy that the government implementing. It also in line with technology adaptation and transfer as required in TEVT policy and strategies.

REFERENCES

1. M.Koç, Y. Sekmen, T.Topgu, and H.S. Yu-cesu, "***The effects of ethanol–unleaded gasoline blends on engine performance and exhaust emissions in a spark-ignition engine***", Renewable Energy. 34, 2101–2106, 2009.

2. M.Eyidogan, A.N. Ozsezen, M. Canakci, T. Ali, ***"Impact of alcohol – gasoline fuel blends on the performance and combustion characteristic of an SI engine",*** Fuel. 89, 2713- 2720, 2010.

3. A.B.Taylor, D.P.Moran, A.J.Bell, "***Gasoline/alcohol blends: exhaust emissions, performance and burn rate in a multi valve production engine***. SAE paper 961988: 143-60, 1996.

4. M. Alexandrian, M.Schwalm, "***Comparison of ethanol and gasoline as automotive fuels***", ASME Paper 92-WA/DE-15.

5. El-Kassaby, M.M. (1993).***Effect of using differential ethanol–gasoline blends at different compression ratio on SI engine***. Alexandria Engng J, Vol.32, No3, pp. 135–142.

6. Al-Hasan, M. (2002). ***Effect of ethanol–unleaded gasoline blends on engine performance and exhaust emission.*** Energy Conversion & Management, Vol.44, No9, pp. 1547–1561.

7. Wu, C.W.; Chen, R.H.; Pu, J.Y. & Lin, T.H. (2004). ***The influence of air–fuel ratio on engine performance and pollutant emission of an SI engine using ethanol–gasoline blended fuels***. Atmospheric Environment, Vol.38, pp. 7093–7100.

8. Koç, M.; Sekmen, Y.; Topgül, T. &Yücesu, H.S. (2009). ***The effects of ethanol-unleaded gasoline blends on engine performance and exhaust emissions in a spark-ignition engine***. Renewable Energy, Vol.34, pp. 2101–2106.

9. Bata, R.V. & Roan V.P. (1989). ***Effects of ethanol and/or methanol in alcohol–gasoline blends on exhaust emission***. J Engng Gas Turb Power, Vol.111, No.3, pp. 432–438.

10. Taylor, A.B.; Moran, D.P.; Bell, A.J.; Hodgson, N.G.; Myburgh, I.S. & Botha, J.J. (1996).Gasoline/Alcohol Blends: ***Exhaust Emissions, Performance and Burn-Rate in a Multi-Valve Production Engine***. SAE Paper, No. 961988, pp. 143–160.

11. Bayraktar, H. (2005). ***Experimental and theoretical investigation of using gasoline–ethanol blends in spark-ignition engines.***Renewable Energy Vol.30, pp.1733–1747.

12. Freeman, J. H. et al., ***American Petroleum Institute Publication*** 4261, 1976

13. Allsup, J. R. and Eccleston, D. B., ***Proceedings*****, Third International Symposium on Alcohol Fuels Technology**, 1979, I

14. Chui, G., Anderson, R. and Baker, R., ***Proceedings, Third International Symposium on Alcohol Fuels*** Technology, 1979, **II**

15. Holger M, Bernd N. ***Engine and vehicle concepts for methanol gasoline blends***. SAE Technical Paper 831686, 1983.

16. Abdel-Rahman, A.A., Osman, M.M., 1997. ***Experimental investigation on varying the compression ratio of SI engine working under different ethanol–gasoline fuel blends***. International Journal of Energy Research 21, 31–40.

*17.*Alexandrian, M., Schwalm, M., 1992. ***Comparison of ethanol and gasoline as automotive fuels***. *ASME papers 92-WA/ DE-15.*

18. Starke, F., ***Proceedings, International Symposium on Alcohol Fuels Technology,*** Wolfsburg, West Germany, 1977

19. American Petroleum Institute (1988) ***Alcohols and ethers: A technical assessment of their application as fuels and fuel components***. API publication N. 4261.

20. Krause, K. (1995) ***Water phase separation in oxygenated gasoline***: Corrected verstion of Kevin Karuse memo. Korotney, D. editor.

21. Lizzio, A.A. (2006) ***Performance of Bio-Tek 70120 alcohol monitor***. Report to Central Illinois Mfg. Co.

22. L.W. Jia, M.Q. Shen, J. Wang, MQ. Lin: ***Influence of ethanol–gasoline blended fuel on emission characteristics from a four-stroke motorcycle engine.*** J Hazard Mater A, 123 (2005), pp. 29–34

23. Holger M, Bernd N. ***Engine and vehicle concepts for methanol gasoline blends***. SAE Technical Paper 831686, 1983.

25. Letcher, "***Ternary phase diagrams for gasoline-water-alcohol mixtures***," *Fuel,* vol.65, 1986.

26. Bechtold, Richard L., "***Alternative Fuels Guidebook: Properties, Storage, Dispensing, and Vehicle Facility Modifications***,"1997

27. Sinor, J.E. & Bailey, B.K. (1993). ***Current and potential future performance of ethanol fuels***. SAE paper 930376, Warren dale, PA.

28. Bailey, B.K. (1997). ***Performance of ethanol as a transportation fuel. Handbook on bio ethanol: Production and Utilization***. Edited by Charles E. Wyman.Applied Energy Technology Series, pp. 37-60.

APPENDIX-A

Some questions are prepared to collect the necessary information for conducting a study on the topic "modification of gasoline fuel system to use gasoline-ethanol-methanol emulsion." Since the success the research significantly depend on your information contribution the researchers will kindly request you to honestly response the questions.

Personal information of the interviewer

Sex ___________________

Age ___________________

Educational level _______________________

Qualification _____________________________

Position in the organization ___________________________

Experience _______________________________

Questions to be asked

1. How much percentage of water exist in the ethanol which is produced in Ethiopia?
2. Would you tell us the cost of the ethanol?
3. How much percentage of ethanol is blended with gasoline?
4. How much percentage of methanol is blended in the conventional fuel?
5. Is there any difference between the cost of gasoline and ethanol-gasoline blend fuel?
6. What is your customer feedback towards the ethanol-gasoline blend fuel?
7. Would you tell us the distribution area of ethanol-gasoline blended fuel? Is it all over the country? Or some specific areas?
8. Would you tell us the distribution area of methanol alcohol fuel? Is it all over the country? Or some specific areas?

APPENDIX-B

Cost analysis

Conversion cost

Below listed are the costs incurred while converting the engine in to a gasoline-ethanol-methanol blend:

No.	List of materials	quantity	Costs in birr
1	Anhydrous ethanol	10lit	134.8 Birr
2	Anhydrous ethanol container	1piec	30 Birr
3	Gasoline fuel	30lit	540 Birr
4	Fuel tank for gasoline	1piec	250 Birr
5	Fuel tank for gasoline-ethanol-methanol	1piec	350 Birr
6	Primary jet and secondary jet	2piec	500 Birr
7	Fuel filter	1piec	400 Birr
8	Fuel hose	1piec	200 Birr
9	Barb fitting for fuel hose	-	100 Birr
10	Labor cost	-	1000 Birr
Total			**5304.8**