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Research Paper

THE EFFECT OF METHANOL - GASOLINE, ETHANOL-GASOLINE AND N-BUTANOL-GASOLINE BLENDS ON THE PERFORMANCE OF 2-STROKE PETROL ENGINE

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This experimental study investigates the effect of using unleaded gasoline and alcohol as additives blends on spark ignition engine (SI engine) performance. Two strokes, single cylinder SI engine were used for conducting this study. Performance tests were conducted for fuel consumption, brake thermal efficiency, brake power, engine power, indicated thermal efficiency and brake specific fuel consumption using unleaded gasoline and additives blends with different percentages of alcohol at varying engine load condition and at constant engine speed. The result showed that blending unleaded gasoline with additives increases the brake power, indicated and brake thermal efficiencies, fuel consumption and mechanical efficiency. The addition of 5% methanol, 5% ethanol and 5% n-butanol to gasoline gave the best results for all measured parameters at all engine torque/power values.

Keywords: Fuel additive, Gasoline-additives blend, Methanol, Ethanol, n-Butanol

INTRODUCTION

Alcohols have been suggested as an engine fuel almost since automobile was invented (Wagner *et al.*, 1979). 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 n-butanol. It is the dream of engineers and scientists to increase the performance of the engine a very limited techniques are available with safety. Additives are integral part of today's 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

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effects even when added in little amount (Gulder, 1979).

In recent years several researches have been carried out to the influence of methanol and ethanol on the performance of spark ignition engines. Alvydas Pikunas *et al.* (2003) presented the influence of composition of gasoline-ethanol blends on parameters of internal combustion engines. The study showed that when ethanol is added, the heating value of the blended fuel decreases, while the octane number of the blended fuel increases. Also the results of the engine test indicated that when ethanol-gasoline blended fuel is used, the engine power and specific fuel consumption of the engine slightly increase.

Effect of ethanol–unleaded gasoline blends on engine performance and exhaust emission was studied by Al-Hasan (2003). A four stroke, four cylinder SI engine (type TOYOTA, TERCEL-3A) Experimental Study of Gasoline-Alcohol Blends on Performance of Internal Combustion Engine 17 was used for conducting the study. The study showed that blending unleaded gasoline with ethanol increases the brake power, torque, volumetric and brake thermal efficiencies and fuel consumption, while it decreases the brake specific fuel consumption and equivalence air-fuel ratio. The 20% vol. ethanol in fuel blend gave the best results for all measured parameters at all engine speeds.

Abu-Zaid *et al.* (2004) introduced an experimental study to investigate into the effect of methanol addition to gasoline on the performance of spark ignition engines. The performance tests were carried out, at variable speed conditions, over the range of 1000 to 2500 rpm, using various blends of methanol-gasoline fuel .It was found that methanol has a significant effect on the increase the performance of the gasoline engine. The addition of methanol to gasoline increases the octane number, thus engines performance increase with methanol-gasoline blend can operate at higher compression ratios.

Experimental Study of Exhaust Emissions and Performance Analysis of Multi Cylinder S.I.Engine When Methanol Used as an Additive studied by Mallikarjun and Venkata Ramesh Mamilla (2009). Experimental study in four cylinders, SI engine by adding methanol in various percentages in gasoline and also by doing slight modifications with the various subsystems of the engine under different load conditions. For various percentages of methanol blends (0-15) pertaining to performance of engine it is observed that there is an increase of octane rating of gasoline along with increase in brake thermal efficiency, indicated thermal efficiency and reduction in knocking.

Balaji (2010) introduced influence of isobutanol blend in spark ignition engine performance operated with gasoline and ethanol. A four stroke, single cylinder SI engine was used for conducting this study. Performance tests were conducted for fuel consumption, volumetric efficiency, brake thermal efficiency, brake power, engine torque and brake specific fuel consumption, using unleaded gasoline and additives blends with different percentages of fuel at varying engine torque condition and constant engine speed. The result showed that blending unleaded gasoline with additives increases the brake power, volumetric and brake thermal efficiencies and fuel consumption addition of 5% isobutanol and 10% ethanol to gasoline gave the best results for all measured parameters at all engine torque values. In this paper we studied the effect of ethanol gasoline blend, ethanol–gasoline blend and mixture ethanol-methanol–gasoline blend, also compare between them.

By considering the environmental and the financial 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.

Statement of the Problem

As the two stroke engines are using different types of fuels like petrol, diesel, gas, etc. In current days the use of two stroke petrol engines is reduced because of emission of harm full gasses, maximum fuel consumption, less efficient. To overcome these difficulties the methanol, ethanol and n-butanol are used as an additive with gasoline to increase the performance of engine and minimize the fuel consumption.

Objective of the Study

The objective of the study is to analyze the performance of the two stroke petrol engine using methanol, ethanol and n-butanol as an additive with the gasoline so as to overcome the above stated difficulties.

Scope of the Study

To increase the performance of the two stroke petrol engine the methanol, ethanol and n-butanol been used as an additive with gasoline. The readings obtained from the conducted tests have been evaluated and the results and graphs are compared.

EXPERIMENTAL SET UP AND PROCEDURE

The engine is 150 cc 2 strokes, single cylinder SI engine loaded by a rope toll dynamometer. Table 1 lists some of the important specification of the engine under test. The schematic layout of the experimental set up is shown in Figure 1. Fuel consumption was measured by using a calibrated burette and a stopwatch with an accuracy of 0.2 sec.

Table 1: Engine Specifications

S. No.	Description	Data
1	Type of engine	Two stroke cycle, single acting air cooled petrol engine
2	No. of cylinder	Single cylinder
3	Max B.P	7.48 HP (5.93 Kw)
4	Max speed	5200 rpm
5	Direction of rotation	Clock wise
6	Bore diameter	57 mm
7	Stroke length	57 mm
8	Cubic capacity	145.45 cc

Figure 1: Experimental Setup for the Effect of Methanol-Gasoline, Ethanol-Gasoline and n-Butanol-Gasoline Blends

Specifications of Other Device and Fluid Used in Experiment

1. Co-efficient of discharge of orifice = 0.6
2. Orifice diameter = 20 mm
3. Density of petrol = 720 Kg/m^3
4. Density of water = 1000 Kg/m^3
5. Calorific value of petrol = 48000 KJ/Kg
6. Calorific value of methanol = 22700 KJ/Kg

7. Calorific value of ethanol = 29700 KJ/Kg

8. Calorific value of n-butanol = 33075 KJ/Kg

The engine was started and allowed to warm up for a period of 15-20 min. The fuel consumption was constant at 10 cc for each performance. Engine test were performed by constant speed and varying the loading condition for each individual fuel. Before running the engine to a new fuel blend, it was allowed to run for sufficient time to consume the remaining fuel from the previous experiment. For each experiment, four runs were performed to obtain an average value of the experimental data.

EXPERIMENTAL DATA

Table 2: For Petrol

Wt in Kg	Speed in rpm N	Time to Consume 10 cc of Fuel in sec	Manometer Reading		
			H1 in cm	H2 in cm	Hw = H1-H2 in mt
2	2950	55	15.1	14.8	0.003
4	2470	53	15.1	14.8	0.003
6	2325	49	15.1	14.8	0.003
8	2200	44	15.1	14.8	0.003

Table 3: For M-5

Wt in Kg	Speed in rpm N	Time to Consume 10 cc of Fuel in sec	Manometer Reading		
			H1 in cm	H2 in cm	Hw = H1-H2 in mt
2	2745	49	15.1	14.8	0.003
4	2150	44	15.1	14.8	0.003
6	1975	41	15.1	14.8	0.003
8	1850	38	15.1	14.8	0.003

Table 4: For E-5

Wt in Kg	Speed in rpm N	Time to Consume 10 cc of Fuel in sec	Manometer Reading		
			H1 in cm	H2 in cm	Hw = H1-H2 in mt
2	2700	59	15.1	14.8	0.003
4	2450	56	15.1	14.8	0.003
6	2340	52	15.1	14.8	0.003
8	2150	49	15.1	14.8	0.003

Table 5: For B-5

Wt in Kg	Speed in rpm N	Time to Consume 10 cc of Fuel in sec	Manometer Reading		
			H1 in cm	H2 in cm	Hw = H1-H2 in mt
2	2550	61	15.1	14.8	0.003
4	2100	57	15.1	14.8	0.003
6	2000	54	15.1	14.8	0.003
8	1950	51	15.1	14.8	0.003

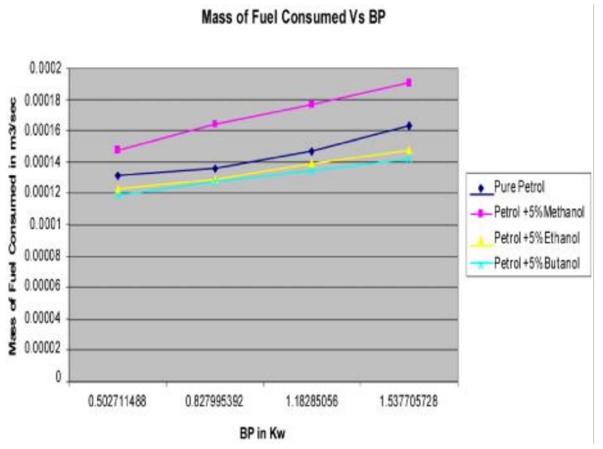
RESULTS AND DISCUSSION

The effect of methanol, ethanol and n-butanol addition to unleaded gasoline on SI engine performance at various engine powers was investigated.

Fuel Consumption

The effect of methanol, ethanol, n-butanol-unleaded gasoline blends on the fuel consumption is shown in Figure 2. From Figure 2, the fuel consumption increases on the engine power increases at engine speed. This behavior is

Figure 2: Fuel Consumption vs Brake Power at Various Loads

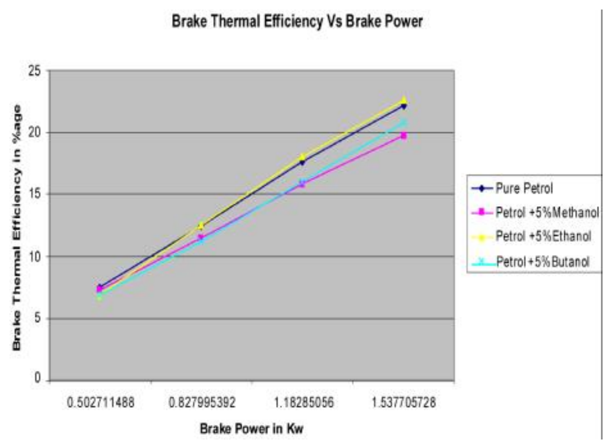


attributed to the Lower Heating Value (LHV) per unit mass of the alcohol fuel, which is distinctly lower than that of the unleaded gasoline fuel. Therefore the amount of fuel introduced in to the engine cylinder for a given desired fuel energy input has to be greater with the alcohol fuel

Brake Thermal Efficiency

Figure 3 presents the effect of methanol, ethanol and n-butanol-unleaded gasoline blends on brake thermal efficiency. As shown in the figure break thermal efficiency increases as the engine torque increases. The maximum brake thermal efficiency is recorded with 5% ethanol in the fuel blend at constant engine speed.

Figure 3: Brake Thermal Efficiency vs Brake Power at Various Loads



Specific Fuel Consumption

The effect of using methanol, ethanol and n-butanol-unleaded gasoline blends on Brake Specific Fuel Consumption (BSFC) is shown in Figure 4. As shown in the figure SFC decreases as the engine torque increases. This is normal consequence of the behavior of the engine brake thermal efficiency.

Mechanical Efficiency

The effect of using methanol, ethanol and n-butanol -unleaded gasoline blends on Mechanical

Figure 4: Specific Fuel Consumption (BSFC) vs Brake Power at Various Loads

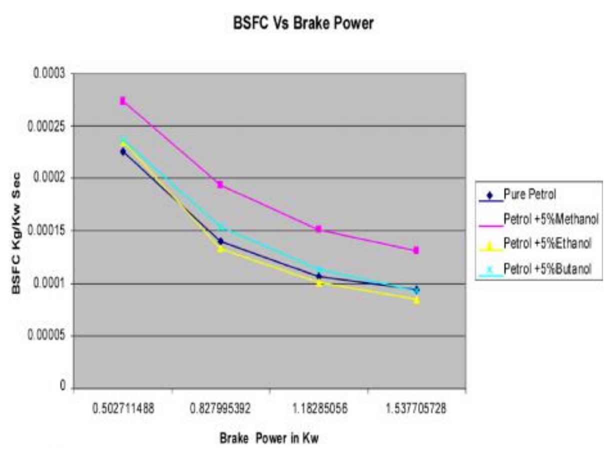
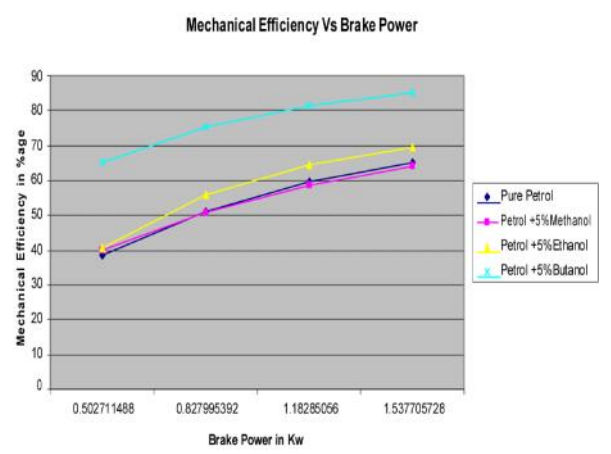


Figure 5: Mechanical Efficiency vs Brake Power at Various Loads

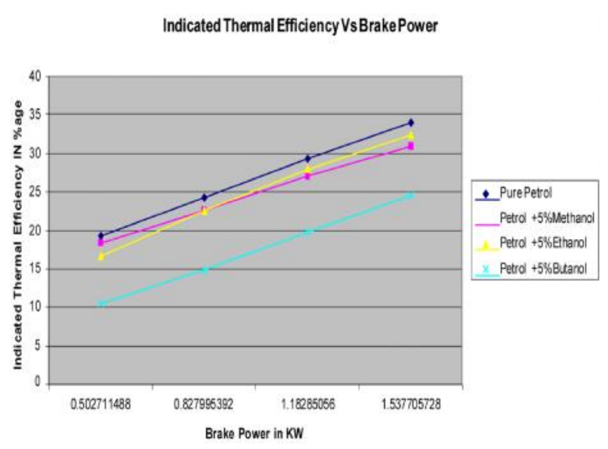


efficiency is shown in Figure 5. As shown in the figure efficiency increases as the engine torque increases. The comparison of efficiency after adding the additive is given below. As the percentage of additives increases in the gasoline, the performance of the engine increases.

Indicated Thermal Efficiency

Figure 6 presents the effect of methanol, ethanol and n-butanol -unleaded gasoline blends on indicated thermal efficiency. As shown in the figure indicated thermal efficiency increases as the engine torque increases. The minimum brake

Figure 6: Indicated Thermal Efficiency vs Brake Power at Various Loads



thermal efficiency is recorded with 5% n-butanol in the fuel blend at engine speed.

CONCLUSION

From the results of the study, the following conclusions can be deduced:

1. Using methanol, ethanol and n-butanol as a fuel additive to unleaded gasoline causes an improvement in engine performance.
2. Methanol, ethanol and n-butanol addition to gasoline results in an increase in brake power, brake thermal efficiency, volumetric efficiency, and fuel consumption respectively.
3. The addition of 5% methanol, 5% ethanol and 5% n-butanol to the unleaded gasoline is achieved in our experiments without any problems during engine operation.

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Research Paper

PERFORMANCE AND EMISSION CHARACTERISTICS BY USING OXYGEN ENRICHED COMBUSTION

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The internal combustion engine is one of the most widely used applications produced by engineering development. However, it is a very limited machine: it has an effective efficiency of 30-35%. This means that almost 70% of the chemical energy contained in the fuel is lost in the coolant, in the exhaust gases, as incomplete combustion of fuel and as radiation. Utilization of oxygen-enriched air in diesel engines holds potential for low exhausts smoke and particulate emissions. The majority of the oxygen enriched-air combustion-related studies so far are experimental in nature, where the observed results are understood on an overall basis. This paper deals with the fundamental considerations associated with the oxygen-enriched air-fuel combustion process to enhance understanding of the concept. The increase in adiabatic flame temperature, the composition of exhaust gases at equilibrium, and also the changes in thermodynamic and transport properties due to oxygen-enrichment of standard intake air are reviewed. The notion of oxygen-enrichment of standard intake air as being akin to leaning of the fuel-air mixture is refuted on the basis of the fundamentally different requirements for the oxygen-enriched combustion process.

Keywords: Oxygen enriched combustion, Adiabatic flame temperature

INTRODUCTION

The purpose of IC engine is the production of mechanical power from the chemical energy contained in the fuel. In IC engines, as distinct from external combustion engines, burning or oxidizing the fuel inside the engine releases this energy. The air fuel mixture before combustion and the burned gases after combustion are actual working fluids. The work transfer which provides output occurs directly between these working fluids and the mechanical components of the engine.

There has been a great concern, in recent years, that the internal combustion engine is

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responsible for too much atmospheric pollution, which is detrimental to human health and environment. Thus it is required to think something in the direction of reducing emission without sacrificing power and fuel consumption.

The principal challenge to continuing success is control of its emission to conform the tightening legislations to protect the environment. If limits of diesel emissions become too stringent, the automotive diesel, for both commercial and private use, may have a very uncertain future and the inherent benefits of the good fuel efficiency is wasted. If not most serious, certainly the most conspicuously annoying feature of the diesel engine is its exhaust smoke. It is often regarded with far more hostility than the relatively invisible engine exhaust.

Most of the diesel engines are now sold with retarded fuel injection timing and a re-optimized lower swirl combustion system to keep NOx levels low. These remedies, however, are reaching their limit of effectiveness. Some diesel engines use EGR to further reduce NOx, particularly for passenger use. Another method of NOx reduction is by utilizing water. Numerous studies are now under way on emulsified fuels and water injection into the air intake pipe or directly into the cylinder. Increasing the concentration of oxygen in the combustion chamber is one method which will reduce HC, CO and smoke and could also improve the brake thermal efficiency. It will also affect the formation of NOx directly and indirectly.

The concept of oxygen enrichment aims at limited substitution of the nitrogen in air by oxygen to achieve low emission levels. Because of the increased oxygen content, additional fuel is burned. The resulting increase in power output is a beneficial offshoot, though it is not attempted for its own sake. Oxygen-enrichment of combustion air provides an opportunity to achieve ignition with minimum amounts of premixed fuel because it reduces the ignition delay period under all operating conditions.

Studies of the effects of oxygen enrichment on direct injection (DI) diesel engine have been carried out with the objective to reduce smoke emissions carried out by Dr R Anand and Dr Mahalakshami. It was found that 25% oxygen enrichment in the inlet air results 10% oxygen flow in the optimum performance and emission characteristics (Anand and Mahalakshami, 2006).

Increasing the oxygen content with the air leads to faster burn rates and the ability to burn more fuel at the same stoichiometery. Added oxygen in the combustion air leads to shorter ignition delays and offers more potential for burning diesel (Rajkumar and Govindrajan, 2010).

Cold-phase emissions was reduced by using oxygen-enriched intake air containing about 23% and 25% oxygen (by volume) in a vehicle powered by a spark-ignition (SI) engine. The experiment was carried out by R. Poola, R. Sekar and

C. Colluci. Test results indicate that the engine-out CO emissions during the cold phase were reduced by about 46 and 50%, and HC by about 33 and 43%, using nominal 23 and 25% oxygen-enriched air compared to ambient air (21% oxygen by volume), respectively. However, the corresponding oxides of nitrogen (NO_3 emissions were increased by about 56 and 79%, respectively (Poola *et al.*, 1995).

The increase in adiabatic flame temperature, the Composition of exhaust gases at equilibrium, and also the changes in thermodynamic and transport properties due to oxygen-enrichment of standard intake air are computed. The effects of oxygen-enrichment on fuel evaporation rate, ignition delay, and premixed burnt fraction are also evaluated. Appropriate changes in the ignition delay correlation to reflect the effects of oxygen-enrichment are proposed by Lahiri and Mehta. There is a considerable increase in thermal conductivity of gases with increase in oxygen enrichment and increase in maximum adiabatic temperature and considerable reduction in ignition delay (Lahiri and Mehta, 1997).

The effects of excess feeding oxygen to the fuel-air mixture on air and fuel mass flow rates and also on air-fuel ratio were investigated here experimentally by Momani *et al.* This study concerned with the effects of injecting pure oxygen quantity to the mixture of fuel and air before interring the combustion chambers. It is found that the mass flow rate of fuel with the oxygen feeding is less than that of with no oxygen feeding at some specific values of engine speeds and the same thing was found for air mass flow rate. The air-fuel ratio also is less with considerable values in the case with oxygen feeding than that with no oxygen samples (Momani *et al.*, 2009).

The experiment was carried out by Sekar and Poola (1997) in which direct injection diesel engine was treated as with intake oxygen level of 35%. They concluded that there is an increase in power density potential with increase in oxygen level. Thermal efficiency and fuel consumption is slightly improved with oxygen enrichment. As NOx emission increases with increase in oxygen enrichment, small amount of water is injected to control the NOx emission. Small emulsification of fuel does not affect the engine performance and reduces NOx emission.

COMBUSTION PROCESS

Combustion processes have been and will be the prime generator of energy to our civilization in the near future. It can be defined as a chemical reaction during which a fuel is oxidized and a large quantity of energy is released, in common, the oxidizer in this process is atmospheric air, specifically the oxygen element in the air, which forms 21% of it. In other words, chemical energy is stored in the fuels, and it's released during combustion process in the form of thermal energy.

The two active elements in fuels are carbon and hydrogen. Ideally, combustion breaks down the molecular structure of the fuel; the carbon oxidizes to carbon dioxide (CO_2) and the hydrogen to water vapor (H_2O), but an incomplete process creates undesirable and harmful products. Carbon can produce two compounds depending on the availability of the air supply and these two compounds are very helpful in analyzing combustion process as the following:

If enough air is supplied to the fuel during combustion, carbon dioxide (CO_2) will appear in the products plus release of heat, and if the supplied air is exactly the theoretical air needed then the exhaust gaseous products consists of 21% carbon dioxide (CO_2), about 78% Nitrogen, and 1% of various gases, plus release of heat.

When the air supply is not sufficient the carbon partially is burnt to carbon monoxide (CO) and the full calorific value of the fuel will not released, this is known as incomplete combustion which is one of the combustion process main sources of heat losses.

There are many contributing reasons to why a combustion process becomes incomplete in an actual case. One of the easiest reasons to see is that a lack of oxygen leaves some of the fuel unburned. But also incompletion can be attributed to insufficient mixing between fuel and oxygen in the combustion chamber due to the short time intervals in which these combustions are occurring. Another cause for incompletion is because of a process called hydrogen bonding. Hydrogen bonding is a process in which chemical bonds form between molecules containing a hydrogen atom bonded to a strongly electronegative atom (an atom that attracts electrons). Because the electronegative atom pulls the electron from the hydrogen atom, the atoms form a very polar molecule, meaning one end is negatively charged and the other end is positively charged. Hydrogen bonds form between these molecules because the negative ends of the molecules are attracted to the positive ends of other molecules, and vice versa.

OXYGEN ENRICHED COMBUSTION

Oxygen Enhanced Combustion (OEC) has become one of the most attracting combustion technologies in the last decade, two developments have increased the significance of it, the first one is the new technology of producing oxygen less expensively and the second one is the increased importance of environmental regulations.

The principle of this technology is to use air with higher oxygen concentration in the combustion process as an intake air, this will reduce the volume of unnecessary nitrogen enters the process. Advantages of oxygen-enhanced combustion include numerous environmental benefits as well as improving energy efficiency and productivity.

METHODS OF OXYGEN ENRICHMENT IN COMBUSTION PROCESS

There are three commonly used methods to enhance combustion process with oxygen:

Air Enrichment: In this method the oxygen is injected into the incoming combustion air supply through a diffuser to ensure adequate mixing. This method may be referred to as low-level O_2 enrichment or premix enrichment. Many conventional air/fuel burners can be adapted for this technology by making small modifications. The advantage of this method that it is usually an inexpensive retrofit that can provide substantial benefits. On the other hand, it has a disadvantage; the added O_2 will shorten and intensify the flame. However, there may be some concerns if too much O_2 is added. The flame shape may become unacceptably short, and the high flame temperature may damage the combustion chamber.

O_2 Lancing: In this method the O_2 is injected directly to the flame describes the process schematically; this O_2 injection method is also generally used for lower levels of O_2 enrichment. However, oxygen lancing may have several advantages over air enrichment. First, no modifications to the existing chamber design need

Figure 1: Air Enrichment Method

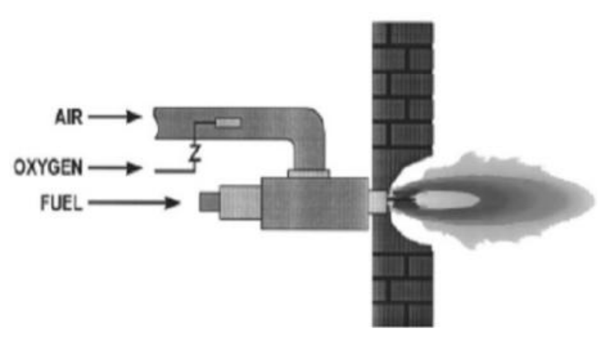
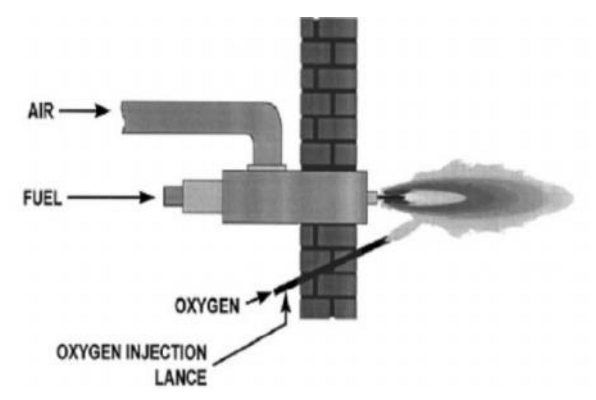


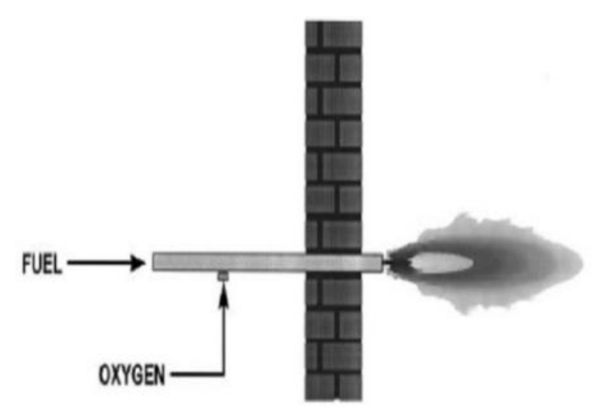
Figure 2: O_2 Lancing Method



to be made. Second, the NOx emissions are lower using O_2 lancing compared with premixing since this is a form of staging, which is a well-accepted technique for reducing NOx. Third, Depending on the injection location, the flame shape may be lengthened by staging the combustion reactions which improves the heat transfer efficiency.

Oxy/Fuel: The third oxygen enrichment method which is mixing O_2 with the fuel supply, it is commonly referred to as oxy/fuel combustion. In this method, high-purity oxygen (>90% O_2 by volume) is used to combust the fuel and it has the greatest potential for improving a process, but it also may have the highest operating cost.

Figure 3: Oxy Fuel Method

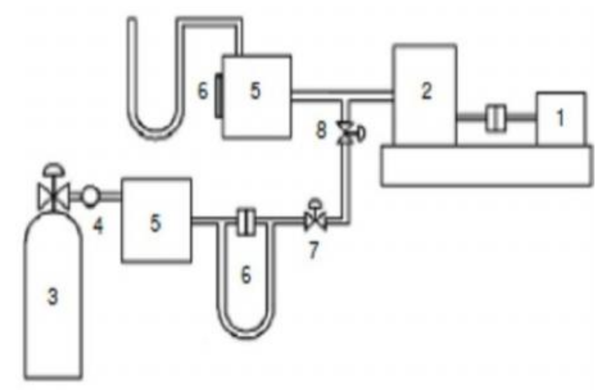


One specific variation of oxy/fuel combustion, known as dilute oxygen combustion, is where fuel and oxygen are separately injected into the combustion chamber. In order to ensure ignition, the chamber temperature must be above the auto-ignition temperature of the fuel.

EXPERIMENTAL SET UP

To perform this experiment a single-cylinder, 4-Stroke, water-cooled diesel engine of 5 hp rated power is considered. The engine is coupled to a rope brake dynamometer through a load cell. The schematic layout of the experimental set up is shown in Figure 4.

Figure 4: Experimental Set Up

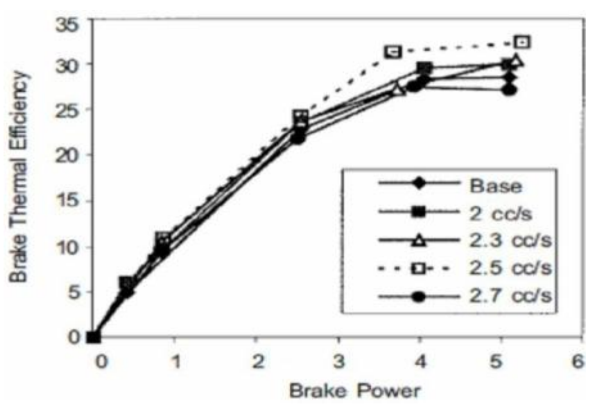


EFFECT OF OXYGEN ENRICHMENT ON THE ENGINE PERFORMANCE AND EMISSION

Brake Thermal Efficiency

There is an improvement in the brake thermal efficiency at all loads when the oxygen flow rate is enhanced as shown in Figure 5. This improvement is may be due to better combustion with enhanced oxygen flow rate. However, brake thermal efficiency falls as the oxygen flow rate is increased to 2.7 cc/s (Udaykumar and Meher, 2004).

Figure 5: Variation of Brake Thermal Efficiency with Brake Power



Specific Fuel Consumption

The variation of Specific Fuel Consumption (SFC) at various power outputs of the base engine is compared with the modified engine at increased oxygen flow rates in Figure 6. There is a fall in the SFC at all loads when the oxygen flow rate is enhanced (Udaykumar and Meher, 2004).

NOx Emission

NOx emission significantly increases with increase in oxygen level. It raises from 625 ppm for the base engine to 878 ppm with 2.5 cc/s flow rate of oxygen level. CO and HC emission

Figure 6: Variation of Specific Fuel Consumption with Brake Power

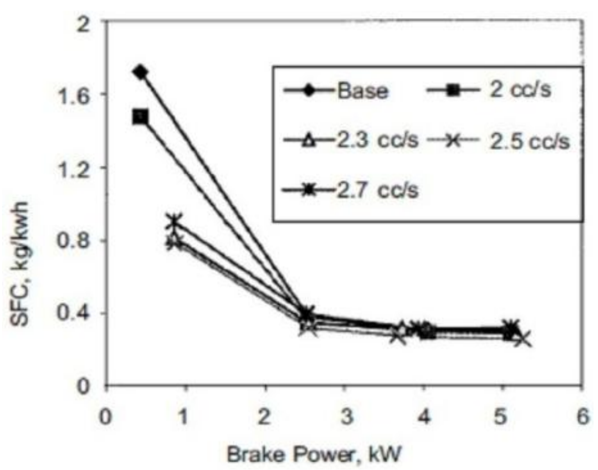
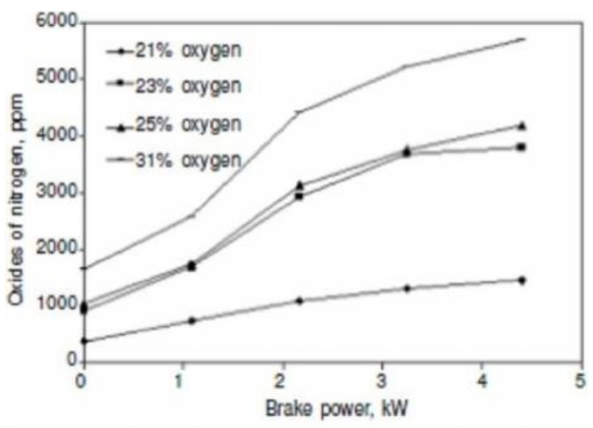


Figure 7: Effect of Oxygen Enrichment on NOx Emission



reduces with increase in oxygen enrichment (Udaykumar and Meher, 2004).

CONCLUSION

It is obvious from the literature review that by increasing the oxygen level in air the combustion efficiency is improved considerably. By using oxygen enriched air the brake thermal efficiency of the engine is considerably increased and it obviously reduces the fuel consumption and CO, HC, PM emission. The aim of the experiment is to find out the correct concentration of the oxygen in atmospheric air to achieve an optimum engine performance and minimum exhaust emission.

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Research Paper

PERFORMANCE AND EMISSION OF METHANOL, ETHANOL AND BUTANOL BLENDS WITH GASOLINE ON SI ENGINE

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Internal combustion engine are the most preferred prime mover across the world. Spark ignition engine is preferred locomotive prime mover due to its smooth operation and low maintains. The gasoline is fossil fuel which is limited in reservoirs causes varieties of study in search of alternative fuel for SI engine, where alcohol promises best alternative fuel. In this paper study of three alcohols are tried to investigate in two parts. Comparative study of methanol, ethanol and butanol on the basis of blending percentage is first part, followed by investigation of oxygen role on the basis of oxygen percentage in the blend. The result shows highest replacement of gasoline by butanol at 5% of oxygen content, the performance of same oxygen percentage for other two alcohols are also better. Presence of oxygen gives you more desirable combustion resulting into low emission of CO, HC and higher emission of CO_2 as a result of complete combustion, higher temperature is also favorable for NO emission resulting higher emissions for it.

Keywords: IC engine, Alcohols, Oxygen basis, Performance of SI engine, Methanol, Ethanol, butanol, Emissions

INRODUCTION

Increased consumption and unstable rates of end prices of fuel made us in various troubles resulting in more attraction of alternative and low cost biofule. Also lavish consumption of fossil fuels has led us to reduction in underground-based carbon resources. The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present days. The fuels of bio-origin can provide a feasible solution to this worldwide petroleum crisis. Also, gasoline and diesel-driven automobiles are the major sources of greenhouse gases emission. Scientists around the world have explored several alternative energy resources, which have the potential to quench the ever-increasing energy

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thirst of todays population and to minimize the emission with higher consumption.

Christoph Baur *et al.* (1990) analyzed the performance of SI engine with Ethyl Tertiary Butyl Ether (ETBE) as a blending component in motor gasoline and compared with ethanol blend.

Presence of oxygen within fuel make fuel to burn clearly with better performance and lower emission and also provide higher octane rating of fuel which allows us to use higher compression ratio, CO and UHC emission levels with ETBE was much lower compared to those with the base gasoline and the NOx emission levels were increased slightly with the oxygenated fuels and was increasing with the increase of the oxygen content in the blended fuels which is related to the greater availability of oxygen and the leaning effect of those oxygenated fuels provides complete combustion of fuel.

Carbon content of any substance directly deal with its heating value, higher the number of carbon higher the calorific value of substance with this as we go with higher alcohol having greater energy per unit which lead to better economy thus Alasfour (1997) (1998a) and (1998b) used butanol as alternative to fuel and additives, the availability analysis of a spark-ignition engine using a butanol-gasoline blend had been experimentally investigated with Hydra single-cylinder, spark-ignition, fuel-injection engine was used over a wide range of fuel/air equivalence ratios (Φ = 0.8-1.2) at a 30% volume butanol-gasoline blend and studied the effect of using a butanol-gasoline blend in a spark-ignition engine in terms of first- and second-law efficiency. In addition, the optimal engine conditions of energy utilization were investigated. Results show that, at Φ = 0.9, when a butanol-gasoline blend is used, the energy analysis indicates that only 35.4% of the fuel energy can be utilized as an indicated power, where 64.6% of fuel energy is not available for conversion to useful work. The availability analysis shows that 50.6% of fuel energy can be utilized as useful work (34.28% as an indicated power, 12.48% from the exhaust and only 3.84% from the cooling water) and the available energy unaccounted for represents 49.4% of the total available energy.

Table 1: Specification of Avl Digas 444 Type Emission Analyzer

S. No.	Measured Values	Measurement Range	Resolution
1	CO	0…10% Vol	0.01% Vol
2	HC	0…200000 ppm	10 ppp (0-2000); 100 ppm (>2000 ppm)
3	CO_2	0…20% Vol	0.1% Vol
4	NO	0…5000 ppm	1 ppm

Further, 30% blend of butanol were investigated for NOx emission by two way dividing two part by preheating the air and by varying the ignition timing, under different values of inlet air temperatures,10% increase in NOx was observed when the inlet air temperature increased from 400 to 608 °C. For 30% iso-butanol-gasoline blend experimental results show that preheating inlet air causes knock and misfire to occur at less advanced ignition timing. Retarding ignition timing causes the engine thermal efficiency to decrease.

Alvydas Pikuna *et al.* (2003) presented the influence of composition of gasoline-ethanol blends on parameters of internal combustion engines. The study showed that when ethanol is added, the heating value of the blended fuel decreases, while the octane number of the blended fuel increases. Also the results of the engine test indicated that when ethanol-gasoline blended fuel is used, the engine power and specific fuel consumption of the engine slightly increase.

Effect of ethanol–unleaded gasoline blends on engine performance and exhaust emission was studied by Al-Hasan (2003). A four stroke, four cylinder SI engine Experimental Study of Gasoline-Alcohol Blends on Performance of Internal Combustion Engine was used for conducting the study. The study showed that blending unleaded gasoline with ethanol increases the brake power, torque, volumetric and brake thermal efficiencies and fuel consumption, while it decreases the brake specific fuel consumption and equivalence air-fuel ratio. The 20% volume ethanol in fuel blend gave the best results for all measured parameters at all engine speeds.

Abu-Zaid *et al.* (2004) introduced an experimental study to investigate into the effect of methanol addition to gasoline on the performance of spark ignition engines. The performance tests were carried out, at variable speed conditions, over the range of 1000 to 2500 rpm, using various blends of methanol-gasoline fuel.

Table 2: General Specification of Engine

S. No.	Specification	Value
1	BHP (Greaves)	3
2	Rated speed	3000 RPM
3	Number of cylinders	1
4	Compression Ratio	2.5:1 TO 8:1
5	Bore	70 mm
6	Stroke length	66.7 mm
7	Type of ignition	Spark ignition
8	Method of loading	DC Generator with Load Bank
9	Method of starting	Crank start-Rope and Motor Start
10	Method of cooling	Forced Air cooled
11	VCR Head Cooling	Water Cooled

It was found that methanol has a significant effect on the increase the performance of the gasoline engine. The addition of methanol to gasoline increases the octane number, thus engines performance increase with methanol-gasoline blend can operate at higher compression ratios.

Cenk Sayin *et al.* (2005) investigated the effect of octane number higher than engine requirement on the engine performance and emissions the trends to use higher-octane rating gasoline than engine requirement of vehicles with carburetor in Turkey have increased the maintenance expenses. Higher octane causes higher ignition temperature at high load and causes sudden and more strong explosion than designed value which cause more wear and tear of engine leading to reduced life of engine

Hakan Bayraktar (2005) developed theoretical model, validating by its experimental results and mentioned the blends including ethanol up to 16.5% by volume can be used in SI engines without any modification to the engine design and fuel system theoretically.

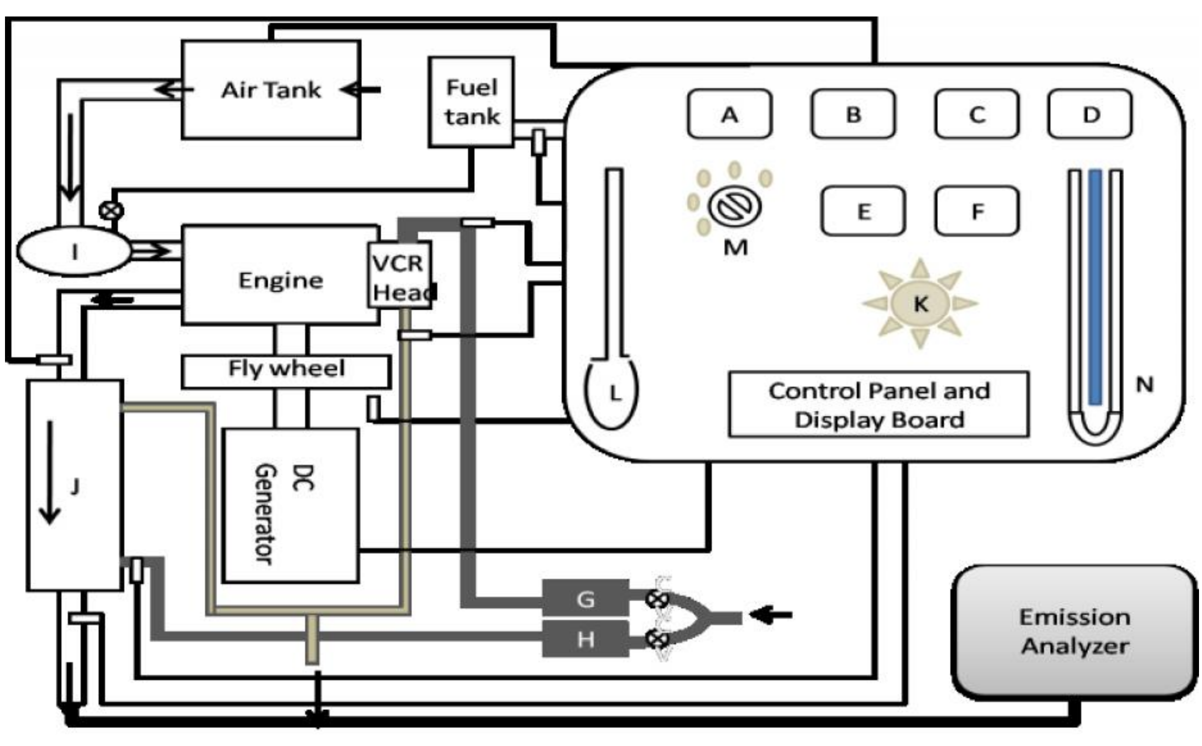
Higher octane rating of alcohol and its blending provides us to work with higher compression ratio; the effect of varying the compression ration with ethanol gasoline blend introduced by Huseyin Serdar Yucesu *et al.* (2006) used three compression ratios, with increasing compression ratio engine torque increased about 8%. At the higher compression ratios the torque output did not change noticeable, highest increment was obtained for fuels E40 and E60 as nearly 14%, considerable decrease of BSFC was about 15% with E40 fuel at 2000 rpm engine speed. Tolga Topgul *et al.* (2006) also investigated the effect of varying compression ratio with hydra engine by varying the ignition timing, blending unleaded gasoline with ethanol increased the brake torque when the ignition timing was retarded.

A 3-cylinder port fuel injection engine was adopted to study engine power, torque, fuel economy, emissions including regulated and non-regulated pollutants and cold start performance with the fuel of low fraction methanol in gasoline by Liu Shenghua *et al.* (2007). Without any retrofit of the engine, the engine power and torque will decrease with the increase fraction of methanol in the fuel blends under Wide Open Throttle (WOT) conditions. However, if spark ignition timing is advanced, the engine power and torque can be improved under WOT operating conditions. Engine thermal efficiency is thus improved in almost all operating conditions. Engine combustion analysis shows that the fast burning phase becomes shorter; however, the flame development phase is a little delay.

Effect of the mixture fuel of ethanol and gasoline on two stroke engine were studied by Ya O li-hang *et al.* (2010) the effect of different ratio of mixed fuel on the characteristics of the engine was tested, when the ethanol content the gasoline was 10% maximum torque and power was obtained and with 20% gasoline minimum fuel consumption rate was obtained with reduced exhaust emission from the engine with alcohol blending.

Experimental Study of Exhaust Emissions and Performance Analysis of Multi Cylinder SI Engine When Methanol Used as an Additive studied by Mallikarjun and Venkata Ramesh Mamilla (2009). Experimental study in four cylinders, SI engine by adding methanol in various percentages in gasoline and also by doing slight modifications with the various subsystems of the engine under different load conditions. For various percentages

Figure 1: Test Rig Setup



of methanol blends (0-15) pertaining to performance of engine it is observed that there is an increase of octane rating of gasoline along with increase in brake thermal efficiency, indicated thermal efficiency and reduction in knocking.

Balaji (2010) mentioned influence of isobutanol blend in spark ignition engine performance operated with gasoline and ethanol. A four stroke, single cylinder SI engine was used for conducting this study. Performance tests were conducted for fuel consumption, volumetric efficiency, brake thermal efficiency, brake power, engine torque and brake specific fuel consumption, using unleaded gasoline and additives blends with different percentages of fuel at varying engine torque condition and constant engine speed. The result showed that blending unleaded gasoline with additives increases the brake power, volumetric and brake thermal efficiencies and fuel consumption addition of 5% isobutanol and 10% ethanol to gasoline gave the best results for all measured parameters at all engine torque values.

Sehaish (2010) compared various blend of gasoline with ethanol and kerosene on different compression ratio and performance of LPG with special arrangement for gas feeding and found the performance of the LPG promising fuel for SI engine, 10% of ethanol is better at all load condition and blend of kerosene should not be used with gasoline looking at highest emission from it.

The comparison among ethanol and butanol was done by Kennneth Szukzyk (2010) on the basis of properties of ethanol and butanol on the basis of their behavior with material and calorific value, which shows butanol as dominant and strong competitor in additives and alternate fuel market.

Huseyin Serdar Yucesu *et al.* (2006) studied Effect of ethanol-gasoline blends on engine

Table 3: Calculations of Properties of Alcohols and Their Blends on the Basis of Replacment Perentage

S. No.	% of Gasoline C.V. = 44.42 KJ/kg	% of Methanol C.V. = 22.70 KJ/kg	% of Ethanol C.V. = 29.70 KJ/kg	% of Butanol C.V. = 33.07 KJ/kg	Calorific Value of Blending (KJ/Kg)	Oxygen % in Blending
Fraction	a	b	c	d	a*G+b*M+c*E+d*B	-
Oxygen % on mass basis	0	0.5	0.3478	0.2667	-	b*M+c*E+d*B
M10	0.9	0.1	0	0	42.248	0.05
M20	0.8	0.2	0	0	40.076	0.1
M30	0.7	0.3	0	0	37.904	0.15
E10	0.9	0	0.1	0	42.948	0.0348
E20	0.8	0	0.2	0	41.476	0.0696
E30	0.7	0	0.3	0	40.004	0.1043
B10	0.9	0	0	0.1	43.285	0.0267
B20	0.8	0	0	0.2	42.15	0.0533
B30	0.7	0	0	0.3	41.015	0.08

Note: * - Data collected from literature.

performance and exhaust emissions in different compression ratios, with increasing compression ratio up to 11:1, engine torque increased with E0 fuel, at 2000 rpm engine speed. Compared with the 8:1 compression ratio, the increment ratio was about 8%. At the higher compression ratios the torque output did not change noticeably. At 13:1 compression ratio compared with 8:1 compression ratio, the highest increment was obtained for both fuels E40 and E60 as nearly 14%.

Ibrahim Thamer Nazzal (2011) investigated the effects of alcohol blends on the performance of a typical spark ignition engine and compared the engine performance with using 12% ethanol-88%gasoline blended fuel and 12% methanol-88%gasoline blended fuel and 6% ethanol-6% methanol – 88% gasoline with gasoline fuel .The engine performance was measured at a variety of engine operating conditions.

The results are presented in terms of speed and their effects are indicated that when ethanol–gasoline and methanol–gasoline blended fuel is used, the brake power of the engine slightly increase. While the brake thermal efficiency showed increase compared with gasoline fuel. At the same time, it is found that *B.S.f.c* also enhance compared with gasoline fuel. The exhaust gas temperature decreased as compared with gasoline fuel.

Objective of this is mainly based on the study of Balaji (2011) and Ibrahim Tharal (2011), they used blends of (isobutanol and ethanol) and (ethanol and methanol) together as a duel blending of alcohol respectively, the close observation of but the study point out the fact of relation between oxygen content and performance of engine with lowered engine emission.

EXPERIMENTAL EQUIPMENTS AND PROCEDURE

Experimentation is carried out on Greaves MK-25 engine which is modifies by Tech-ed equipments limited, Bangalore. Basically MK-25 was designed with f-shape combustion chamber which was then replaced by over head piston, the up and down movement of piston causes change in clearance volume of engine resulting into change in compression ratio. Over head piston displacement allows changing compression ratio of engine from 2.5 to 8, further detail of engine and setup is described below. Primary goal of study is to find out the effect of oxygen percentage of alcohol on performance of IC engine. The engine is governed by mechanical governor which allow us to run engine at constant speed. Engine is coupled with DC dynamometer through constant load bank then load is varied by varying field voltage, generation efficiency for given loading which less than half is taken as 70%. Various parts of engine are shown in Figure 1 and specification in Table 2, none contact type tachometer (Range 0-50000 rpm, 0.05%±1) is used to measure the speed of engine mounted below flywheel, engine is force air cooled but the VCR head is provided with water cooling. Load cell is to measure the fuel consumption rate, for verification manual burette measurement is also provided. Likewise, with digital meter and manual u tube manometer mounted for volumetric measurement of air in through air box with orifice of 20 mm. K-type thermocouples (0-600 °C) are used for measurement of various temperatures. For measurement of exhaust gas emission AVL Digas 444 type emission analyzer is used. Detail of emission gas analyzer is shown is in Table 1. Blends of methanol, ethanol and butanol is prepared on the basis of replacement percentage

Table 4: Calculations of Properties of Alcohols and Their Blends on the Basis of Oxygen Percentage

S. No.	% of Gasoline C.V. = 44.42 KJ/kg	% of Methanol C.V. = 22.70 KJ/kg	% of Ethanol C.V. = 29.70 KJ/kg	% of Butanol C.V. = 33.07 KJ/kg	Calorific Value of Blending (KJ/Kg)	Oxygen % in Blending
Fraction	a	b	c	d	a*G+b*M+c*E+d*B	-----
Oxygen % on mass basis	0	0.5	0.3478	0.2667	-------	b*M+c*E+d*B
M5	0.95	0.05	0	0	43.33	0.025
M10	0.9	0.1	0	0	42.25	0.05
M15	0.85	0.15	0	0	41.16	0.075
E7	0.928	0	0.072	0	43.36	0.025
E14	0.8561	0	0.1439	0	42.3	0.05
E21	0.7845	0	0.2155	0	41.25	0.075
B12	0.8845	0	0	0.1155	43.11	0.025
B23	0.7687	0	0	0.2313	41.79	0.05
B35	0.653	0	0	0.347	40.48	0.075

Note: * - Data collected from literature.

followed by matching oxygen percentage as shown in Tables 3 and 4 respectively, the properties of fuels are calculated on the basis values available and validated with literature available. The blending of methanol ethanol and butanol is referred with M, E and B followed with percentage of blending.

The engine is started and allowed to warm up for 10-15 min, the engine is allowed to maintain speed of 3000 rpm and load is varied from zero to full load with variac mounted on panel, each reading was allowed to stable for 10min and then respective reading of various parameters were taken. The tests were carried out by adjusting the fuel valve for leaner condition.

RESULTS AND DISCUSSION

Part1- Comparative Study of Tree Alcohols

Brake Thermal Efficiency

Brake thermal efficiency is the function of actual power gain from total supplied energy input. More heat input gives you better results thus higher the calorific value of fuel and better the performance, table shows highest calorific value for the gasoline clearly pointing for better thermal efficiency of gasoline than any other blending. But, graph for methanol blending shows higher thermal efficiency for M10 blend.

Even with lower calorific value, result for methanol blend is higher the reason behind the performance is the presence of oxygen in blend, 5% oxygen contain give more desirable combustion than that of plain gasoline resulting into increase brake mean effective pressure which gives higher thermal efficiency.

Graph (Figure 2) shows comparison of three blends of methanol, the thermal efficiency of M10 blend is highest but then after the thermal efficiency for further blends of methanol shows lower performance even with higher oxygen contain. The Higher oxygen give use more desired

Figure 2: Brake Thermal Efficiency of Methanol Blends

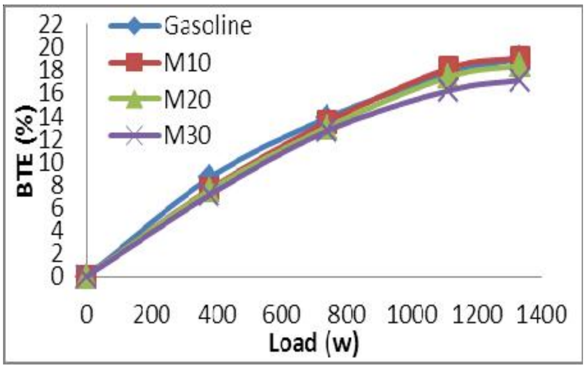
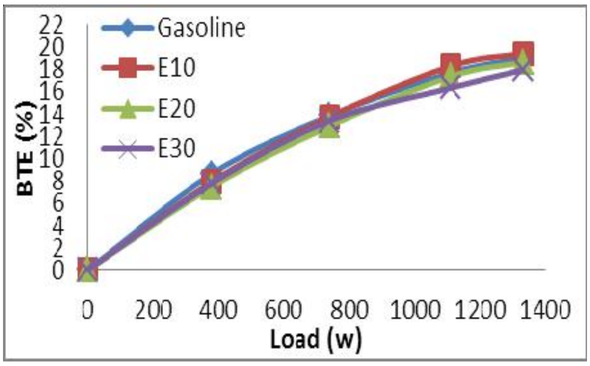


Figure 3: Brake Thermal Efficiency of Ethanol Blends

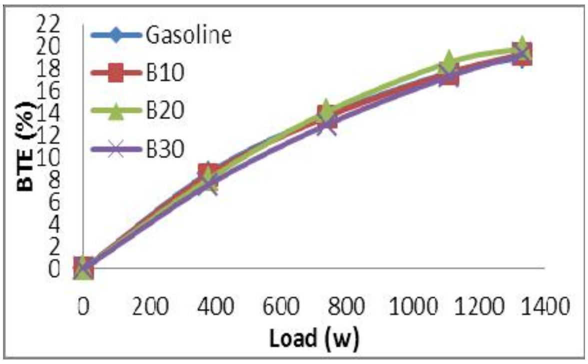


combustion but it is not satisfactory to overcome the effect of the lower calorific value thus only particular amount of alcohol is allowed to blend with gasoline without any modification.M30 blend shows you lowest thermal efficiency having lowest calorific value. Behavior of graphs plotted (Figure 3) for various blend of ethanol follows the similar pattern, blend E10 shows better performance than other two blending, but the performance of E10 is somewhat better than M10 as result suggest, it may be result of oxygen compensation for ethanol blend is better than methanol blend resulting into better performance of E10blends.Also calorific value for ethanol is higher than that of methanol that is another reason for higher thermal efficiency of ethanol blend. Likewise the performance of E20, E30 is lower than E10, but is parallel comparison with methanol; ethanol shows better performance as discussed. M30 shows lowest brake thermal efficiency at full load condition.

The tests were further carried out with the blending of butanol in proportion 10, 20, 30. The calorific value for butanol is higher than that of other two alcohols, which allows greater replacement of fossil gasoline. The calorific value amongst blending is highest for B10 as table indicates with lowest oxygen percentage. Graph plotted (Figure 4) for comparison of performance of thermal efficiency for different butanol blends shows better performance for B20 blend, when we observe closely the calorific value and presence of oxygen play important role in alcohol blending likewise in E10 the percentage of oxygen is nearer to the five percent and thus in comparison butanol shows better result. Further increase in butanol in blend shows similar results as seen in case of methanol and ethanol.

Overall, it is observed that the performance of butanol with twenty percent blending gives higher replacement of fuel with better thermal efficiency without any modification.

Figure 4: Brake Thermal Efficiency of Butanol Blends



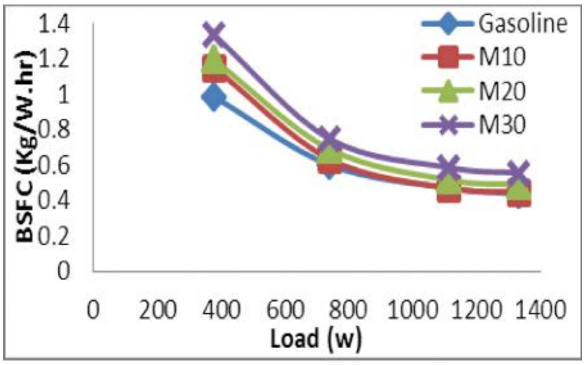
Brake Specific Fuel Consumption

Fuel consumed for one kilowatt power generation in one hour is defined as brake specific fuel consumption. The brake specific fuel consumption decreases when heading towards loading condition, brake specific fuel consumption for full load condition is least. Comparison with fuel consumption shows you opposite trend of graph, fuel consumption increases with increase in load but brake specific fuel consumption decreases with increase in load as it is function of fuel consumption and brake power

Graph plotted (Figure 5) for methanol blend showing brakes specific fuel consumption at various loading condition. Graph shows least fuel consumption of fuel for initial loading of gasoline blend, but at full loading condition the brake specific fuel consumption for M10 is least. The brake specific fuel consumption for M30 shows highest value on graph.

Better thermal efficiency of M10 as discussed before is resulting of complete combustion and thus M10 shows least brake specific fuel consumption. Result of other two blends is as expected from brake thermal efficiency graph; the brake specific consumption is higher for it. Lower calorific value of methanol blends need higher fuel

Figure 5: Brake Specific Fuel Consumption for Methanol Blends



supply for producing same power at given rpm. Likewise the brake specific fuel consumption for butanol at twenty percent and for ethanol at ten percent show least brake specific fuel consumption (Figures 6 and 7). The lower calorific values of blending resulting into higher fuel consumption thus considering brake specific fuel consumption rather than fuel consumption gives you better analytical results.

Emissions

CO

Carbon monoxide is product of incomplete combustion of fuel. Formation of carbon monoxide indicates loss of power, result of oxygen deficiency in combustion chamber.

Figure 6: Brake Specific Fuel Consumption for Ethanol Blends

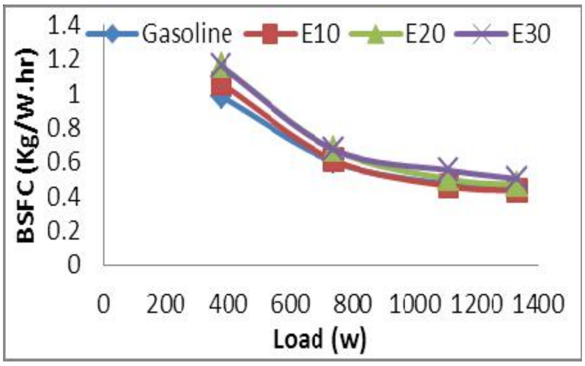
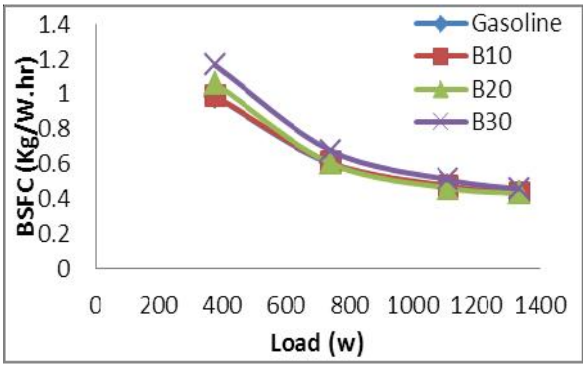


Figure 7: Brake Specific Fuel Consumption for Butanol Blends



Emission of CO is unavoidable with available technology, since it is not possible to achieve supply of required air with proper mixing in combustion chamber which can sufficiently burn all fuel or even with higher air, the emission of carbon monoxide increase result of higher oxygen molecule.

In particular case the carbon mono oxide shows increasing trend for higher loading the result may be due to less reaction time for more fuel supplied.

The blends of methanol in graph shows lower carbon monoxide emission compared to gasoline, primarily presence of oxygen can be considered as reason for reduction in CO emission further it is validated by higher blending of methanol. Methanol with thirty percent has highest oxygen showing lowered emission of CO. The graphs (Figure 8) for ethanol and butanol also shows similar trend of CO emission. Butanol with 30% blending percentage shows least emission of CO.

HC

Hydrocarbon is also product of incomplete combustion of fuel. The formation of hydrocarbon is due to lack of complete air supply. The results

Figure 8: CO Emission with Varying Load on Replacement Basis

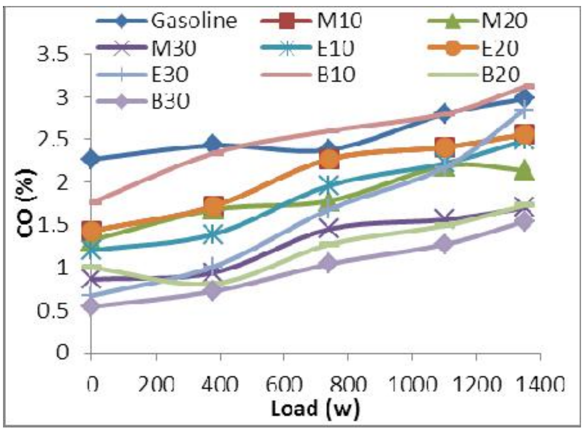
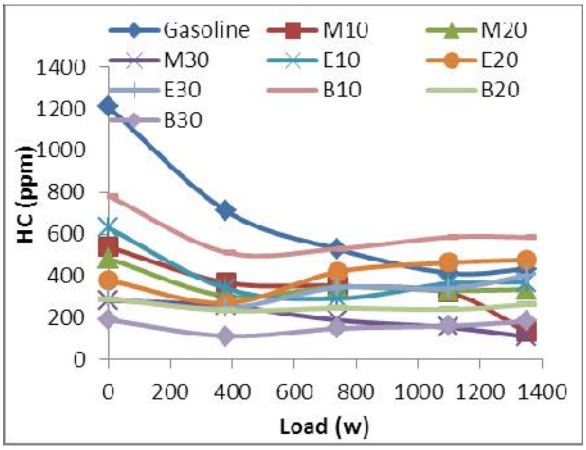


Figure 9: HC Emission with Varying Load on Replacement Basis



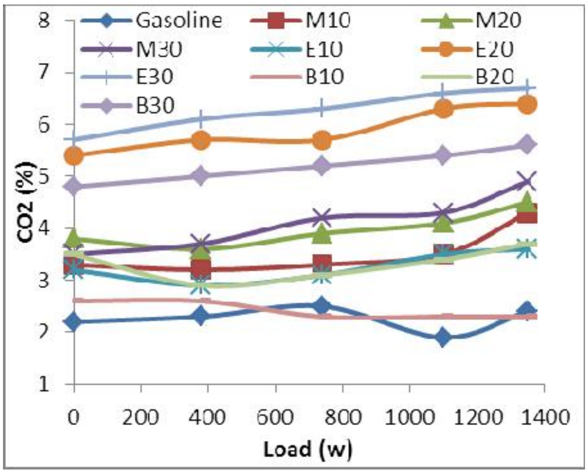
obtained for alcohols blending are plotted against different loading condition. HC emission indicate power loss, higher the hydrocarbon emission higher the power loss resulting into less brake thermal efficiency. Complete combustion for HC then can be achieved by after treatment processes. Addition of alcohol gives you lesser hydrocarbon emission eliminating need of after burner and other devices. When gasoline tested of engine the HC emission was significantly high. But with addition of methanol, hydrocarbon emission lowered down significantly. The emission for hydrocarbon shows declined trend for higher loading. Higher loading resulting into higher brake mean effective pressure resulting into higher temperature which facilitates more rapid and complete burning of fuel which is further improved with addition of oxygenated alcohols.

The graph plotted show least hydrocarbon emission for M30blend result of more oxygen and complete combustion. HC emission is also function of lean mixture and the setting was made to attain leaner mixture for better emission.

CO_2

Unlike CO and HC, Carbon dioxide is product of complete combustion of fuel and higher emission of CO_2 is desirable. When hydrocarbon burns in presence of sufficient air then it generates heat producing carbon dioxide and water as final product of reaction. Normally, CO_2 emission increases with increase in load as seen from graph (Figure 10) further presence of alcohol provides more oxygen for combustion of fuel thus the emission of CO_2 increases with increase oxygen percentage of alcohol blends. The only way to control carbon dioxide emission is to burn less fuel efficiently by using more efficient engine. Emission for ethanol is better than then that methanol and butanol.

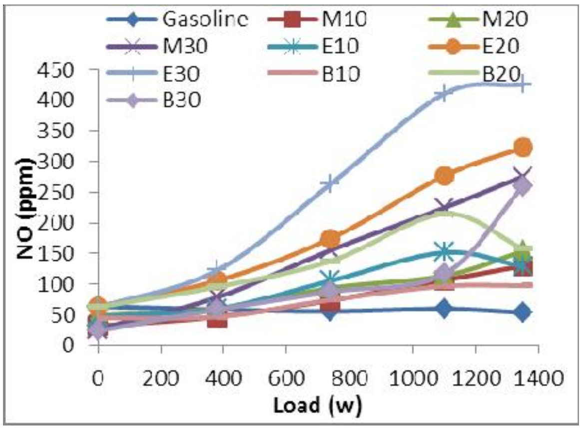
Figure 10: CO_2 Emission with Varying Load on Replacement Basis



NO

Formation of nitrogen oxide is an endothermic process which absorbs heat from surrounding lowering down the temperature of surrounding. NO formation occurs at low equivalence ration and high adiabatic flame temperature. NO can be controlled by lowering down the flam temperature. As the oxygen percentage increase provides complete combustion with higher temperature resulting in higher NO formation as observed in graph (Figure 11), also the graph shows increasing trend of NO for increase loading.

Figure 11: NO Emission with Varying Load on Replacement Basis



Part 2: Performance of Alcohol Gasoline Blend on the Basis of Oxygen Percentage in the Blend

Brake Thermal Efficiency

Thermal efficiency if function of calorific value and brake power, we discussed effect of calorific value and presence of oxygen with in blend in Part 1. The presence of oxygen to particular level gives you complete combustion which compensate the effect of calorific value based

Figure 12: Brake Thermal Efficiency for Methanol Blends of Oxygen Basis

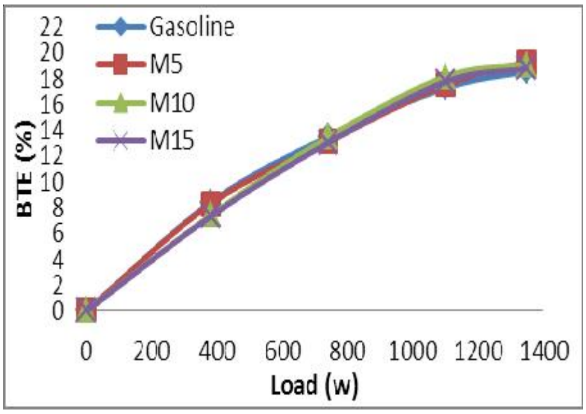


Figure 13: Brake Thermal Efficiency for Ethanol Blends of Oxygen Basis

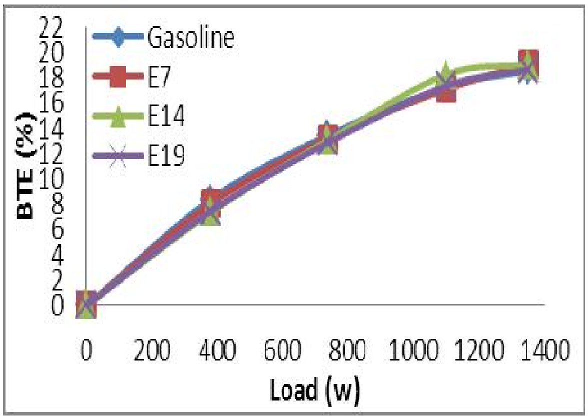
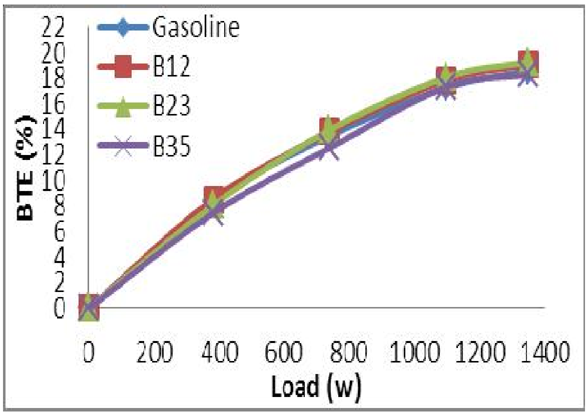


Figure 14: Brake Thermal Efficiency for Butanol Blends of Oxygen Basis

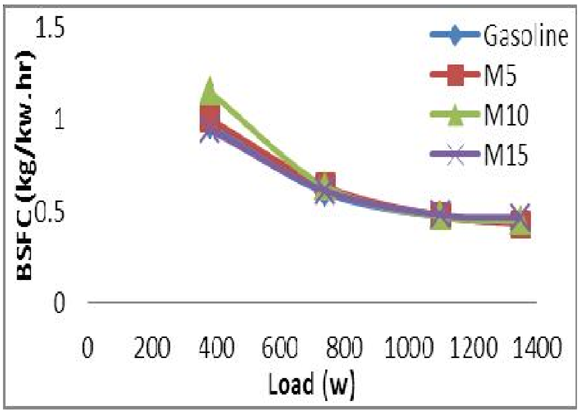


same phenomenon, blending of alcohols are made on the basis of matching oxygen percentage.

The same oxygen percentage for different alcohols represents same calorific value thus expecting similar performance. Table 5.1 shows properties of different blend of alcohols used for current experimentation.

Results obtained are plotted against varying loading condition, the results obtained are better for M5 and indicates better performance for methanol (Figure 12). Likewise the test of ethanol

Figure 15: Brake Specific Fuel Consumption for Methanol Blends of Oxygen Basis



and butanol show similar behavior for the graph of matching oxygen (Figures 13 and 14) overall presence of 5% oxygen in all the blends of methanol, ethanol and butanol shows better results of brake thermal efficiency. The differences in values may be result of experimental error. The combustion chemistry for all alcohol play important role and thus the rate of heat release can make difference in performance of engine.

But, the results indicated on the graph represent almost matching performance of alcohol blend for matching oxygen percentage.

Figure 16: Brake Specific Fuel Consumption for Ethanol Blends of Oxygen Basis

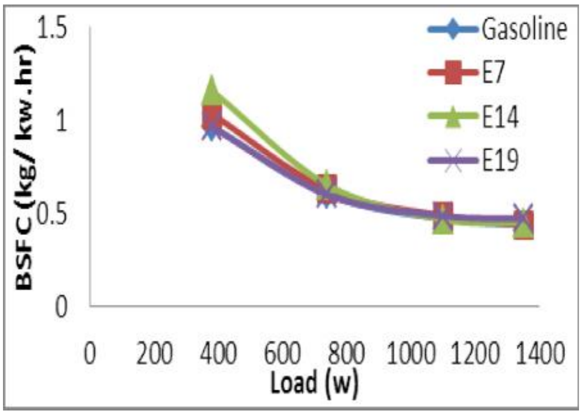
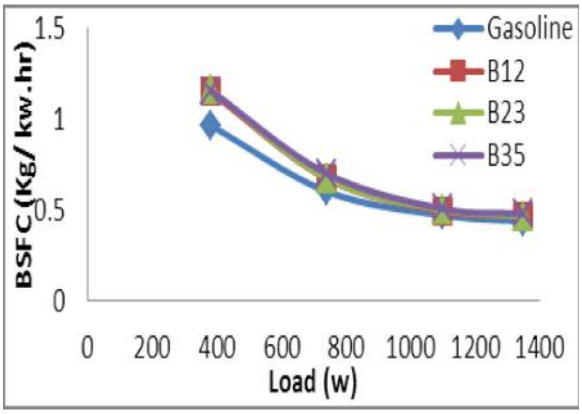


Figure 17: Brake Specific Fuel Consumption for Butanol Blends of Oxygen Basis



Brake Specific Fuel Consumption

2.5% oxygen in blend gives complete combustion and thus calorific value compensated by complete combustion of fuel. Compensation of fuel heating value by oxygen presence is observed up to blending of 5% oxygen contain within blend. Thus replacement of highest 23% of gasoline can be possible with the help of butanol as the trend lines of graph drawn for brake specific fuel consumption indicates.

Emission

CO

CO is result of incomplete combustion of fuel or result of excess of air. In this section the graph (Figures 18, 19 and 20) for carbon monoxide on the basis of matching oxygen percentage are plotted.

Particular engine for compression ratio of 6 shows increasing trend of emission of CO with increase loading. The oxygen percentage of 7.5% in blend shows lowest emission of carbon monoxide which is result of complete combustion of fuel due higher oxygen percentage.

HC

Hydrocarbon carbon emission decreases with

Figure 18: CO Emission for Blends of Methanol Blends of Oxygen Basis

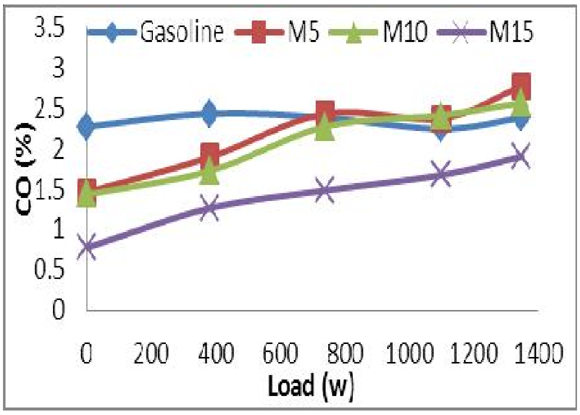


Figure 19: CO Emission for Blends of Ethanol Blends of Oxygen Basis

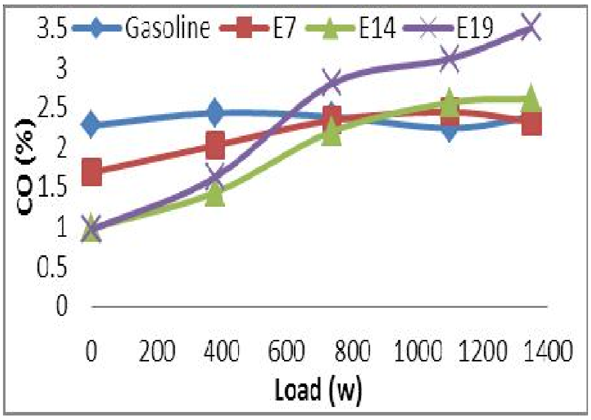


Figure 20: CO Emission for Blends of Butanol Blends of Oxygen Basis

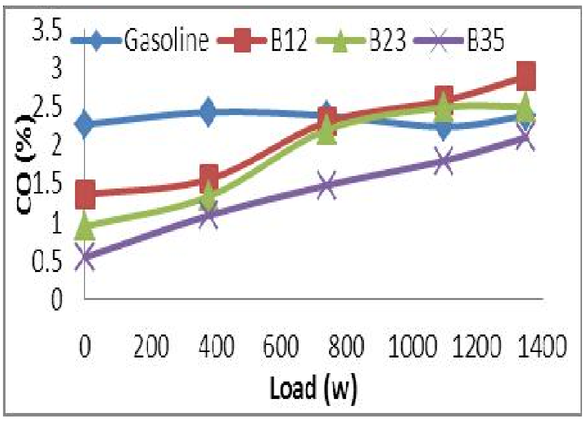


Figure 21: HC Emission for Blends of Methanol of Oxygen Basis

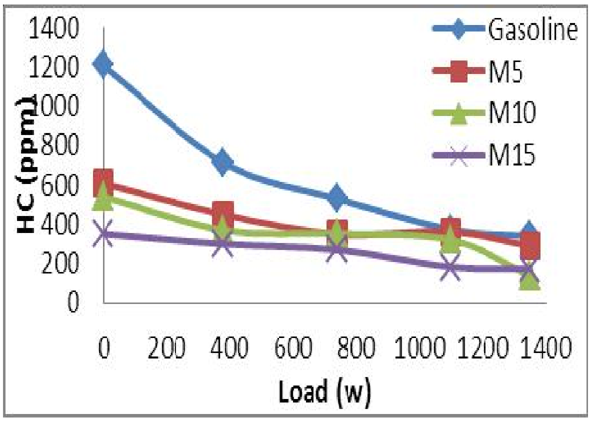


Figure 22: HC Emission for Blends of Ethanol of Oxygen Basis

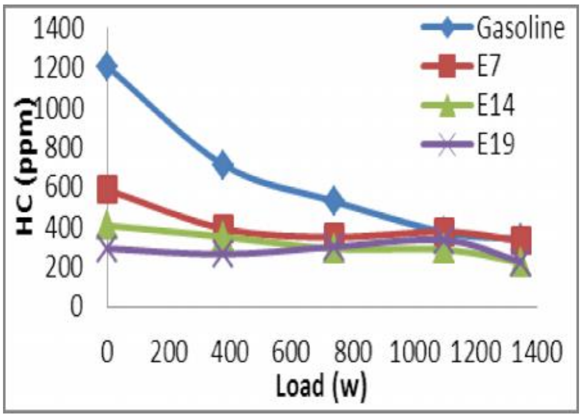
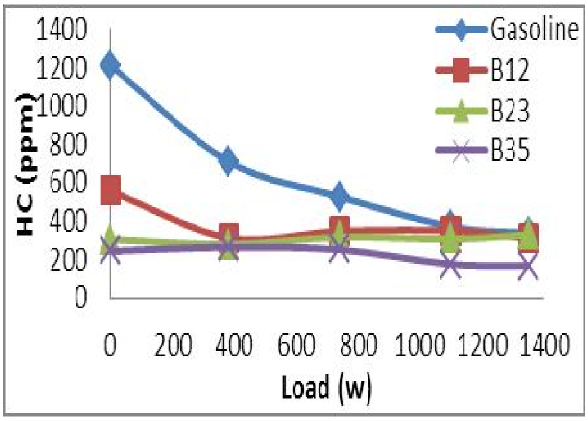


Figure 23: HC Emission for Blends of Butanol of Oxygen Basis



increasing loading on engine unlike carbon monoxide. Unburned hydrocarbons are always result of improper burning of fuel. Also the rate of combustion or reaction increases with increase in temperature which results into lower hydrocarbon emission.

Carbon monoxide emissions for alcohol are lower than that of gasoline which is result of complete combustion. Similarly the hydrocarbon emission decreases with presence of alcohol. The trend observed from the graph (Figures 21, 22 and 23) plotted shows the same trend of hydrocarbon emission for methanol, ethanol and butanol. The value for the graph and blends are different but the emission following a sequence.

CO_2

Emission of CO_2 increases with increase in load and is highest for M15, 7.5% of oxygen give you more oxygen resulting into more complete combustion of fuel and thus carbon dioxide emission increases.

The emission for M5, E7 and B12 is least among blending, and trend observed for the comparison of matching oxygen percentage shows expected result of matching trend of

Figure 24: CO_2 Emission for Blends of Methanol of Oxygen Basis

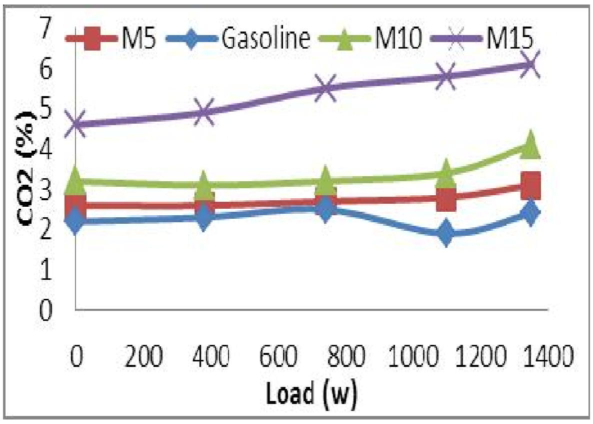


Figure 25: CO_2 Emission for Blends of Ethanol of Oxygen Basis

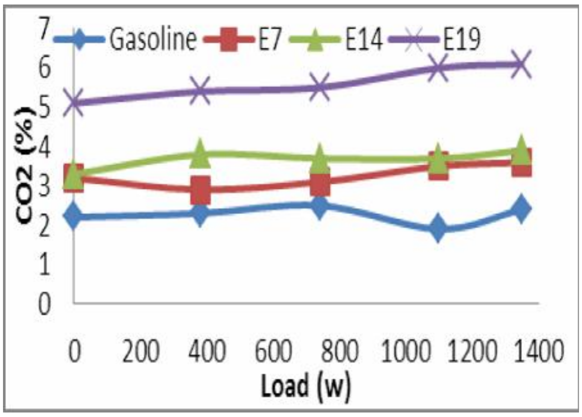
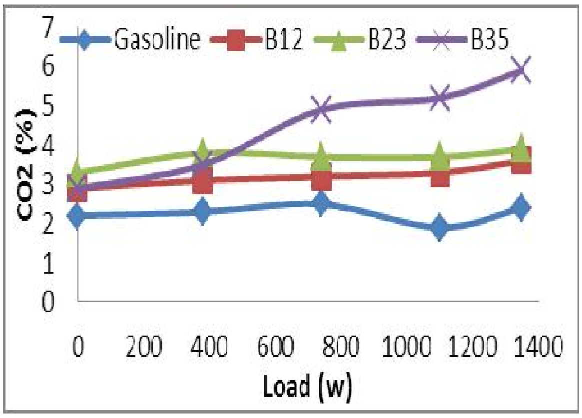


Figure 26: CO_2 Emission for Blends of Butanol of Oxygen Basis



carbon dioxide emission for methanol, ethanol and butanol blending.

NO

Trend of oxide emission of nitrogen is again same in comparison with three alcohols.

Brake Thermal Efficiency for Various Blends of Butanol

Brake thermal efficiency of butanol blends are plotted for various blends of butanol with different oxygen percentage, it is seen that the value of brake thermal efficiency increases with increase in blending percentage and oxygen content.

Figure 27: NO Emission for Blends of Methanol of Oxygen Basis

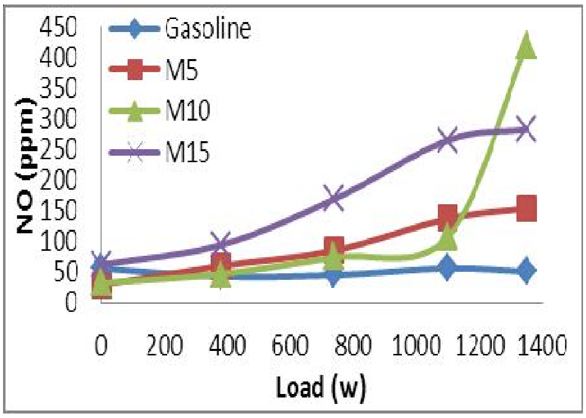


Figure 28: NO Emission for Blends of Butanol of Oxygen Basis

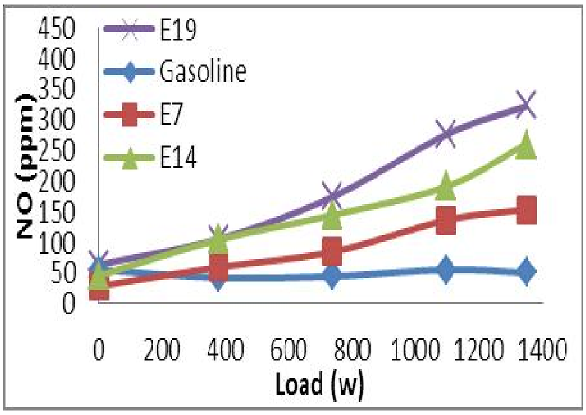


Figure 29: Brake Thermal Efficiency for Various Blends of Butanol at Different Load

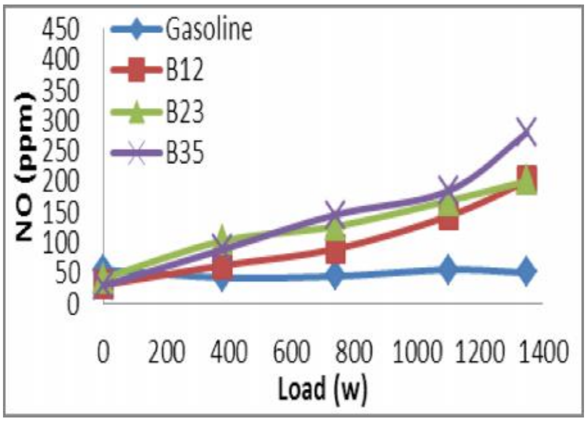
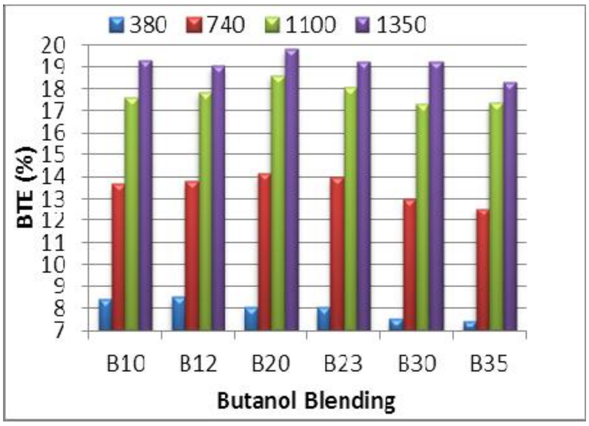


Figure 30: NO Emission for Blends of Ethanol of Oxygen Basis



Blends of butanol at oxygen content around 5% give higher thermal efficiency then shows lowered efficiency for higher blends. Complete combustion resulting into higher thermal efficiency at particular blend.

CONCLUSION

Brake thermal efficiency increases for particular alcohol blending percentage and the percentage of blending for different alcohols are different. After particular fix percentage, the performance of alcohol blending decreases, the alcohol in gasoline provide oxygen which result into more desirable combustion of fuel.

These combustion of fuel gives higher brake mean effective pressure which compensate the effect of low heating value or even rise of pressure cause higher thermal efficiency. After particular blending percentage, the effect of complete combustion is incapable of minimizing the effect of lower calorific value thus break thermal efficiency decreases. Performance of M10, E10 and B20 among tested fuel shows better result within group of same alcohol blends. Close observation of three blends for different percentage blend shows better engine performance around blend of 4 to 6 oxygen percentage as part 1 of experimentation indicates. Fuel prepared on the basis of oxygen percentage is tested in 2nd part of experimentation; result shows parallel performance of engine. As oxygen percentage matches the resulting heating value has same number as seen in table IV and thus presence of oxygen has significance on calorific value, the performance of alcohol gasoline blend containing oxygen equal to 5% shows better performance for all three alcohols followed lower thermal efficiency at higher oxygen content.

Addition of oxygenates in gasoline provides better combustion resulting into significant reduction in CO and HC emission. These provides heat addition to actual performance their by increase break thermal efficiency of engine. It is observed that the CO and HC emission reduces with increase in oxygen contain when we consider blends of methanol, the emission for CO and HC is least for M30 almost at all operating conditions.CO and HC after complete combustion produces CO_2 and water for HC, thus result of which show increased percentage of carbon dioxide. Also the carbon dioxide emission increases with increase in load as inverse to HC emission. Nitrogen in air reacts with available oxygen at higher temperature; the condition of better combustion produces higher temperature resulting into increased combustion for oxides of nitrogen. Further increase in load causes even higher temperature resulting into higher NO emission as observed. As the oxygen contain increases, normally more desirable combustion observed in most of the cases and thus the emission for CO_2 increases for 7.5% oxygen containing blend than 5% and 2.5% of oxygen contain. And CO, HC emission decreases.

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