

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 CO₂ 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 today's 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 makes fuel to burn clearly with better performance and lower emission and also provides higher octane rating of fuel which allows us to use higher compression ratio, CO and UHC emission levels with ETBE were much lower compared to those with the base gasoline and the NO_x emission levels were increased slightly with the oxygenated fuels and were 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 deals 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 leads 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 ($\Phi = 0.8-1.2$) 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 $\Phi = 0.9$, when a butanol-gasoline blend is used, the 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

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.

Further, 30% blend of butanol were investigated for NO_x emission by two ways: dividing two parts by preheating the air and by varying the ignition timing, under different values of inlet air temperatures, 10% increase in NO_x 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.

S. No.	Specification	Value
1	BHP (Greaves)	3
2	Rated speed	3000 RPM
3	Number of Cylinders	4
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.

Yildirim *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.

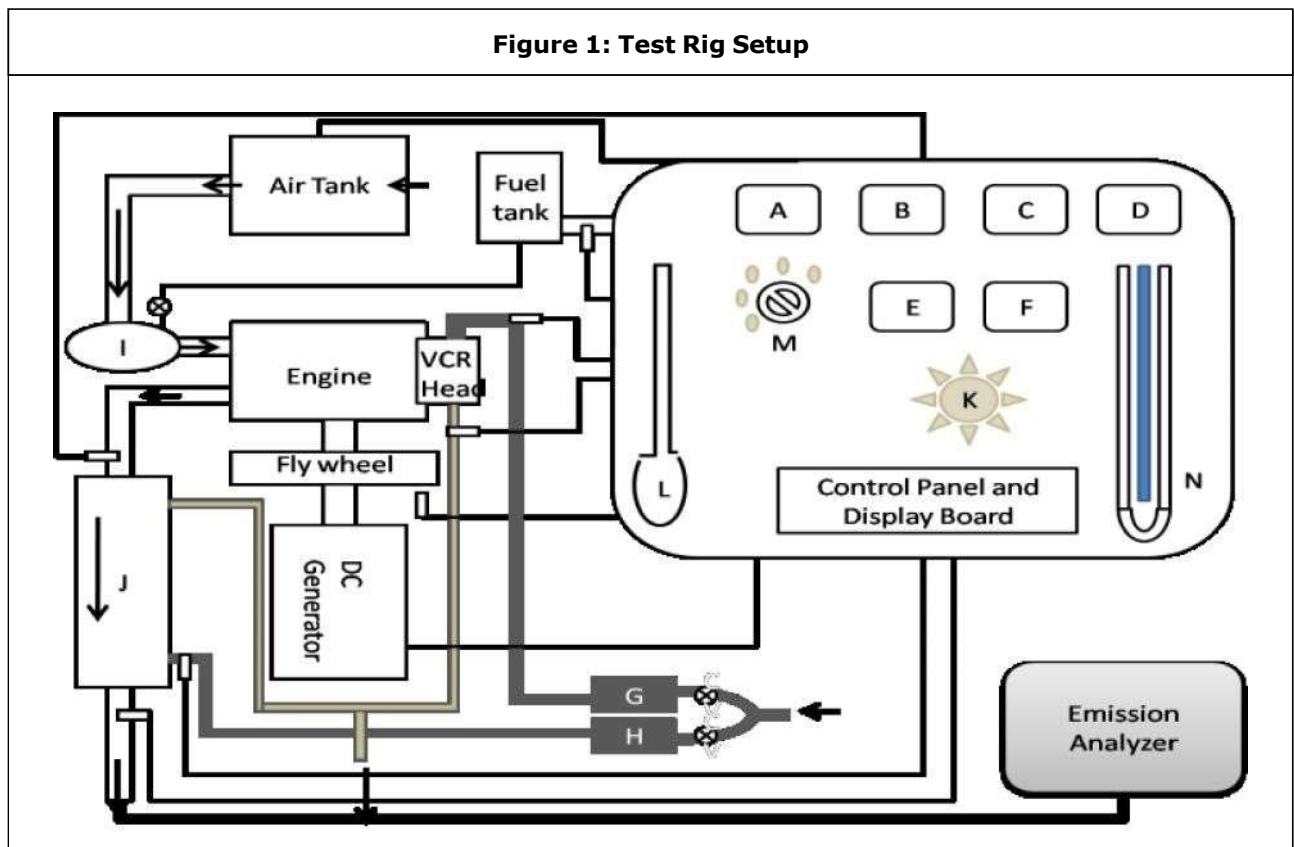
Higher octane rating of alcohol and its blending provides us to work with higher compression ratio; the effect of varying the compression ration with ethanol gasoline blend introduced by Huseyin Serdar Yucesu *et al.* (2006) used three compression ratios, with increasing compression ratio engine torque 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



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 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	-	$b^*M+c^*E+d^*B$
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 dual 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 modified 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, non 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 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

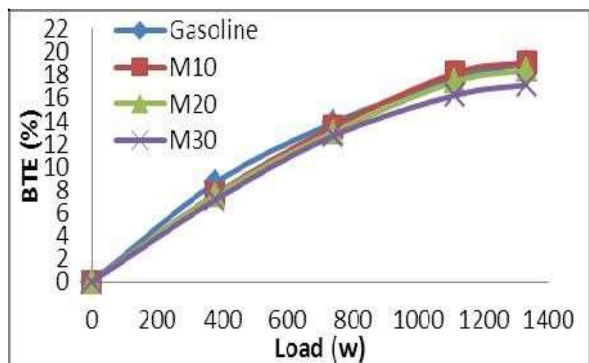
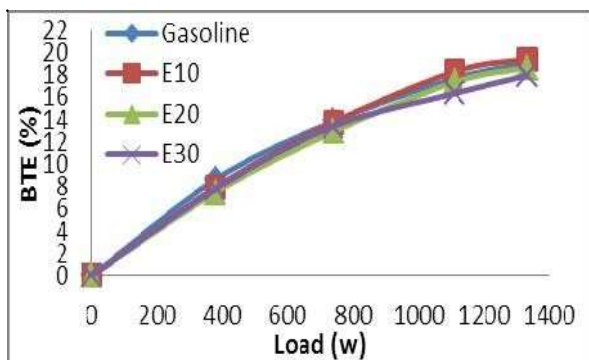


Figure 3: Brake Thermal Efficiency of Ethanol Blends



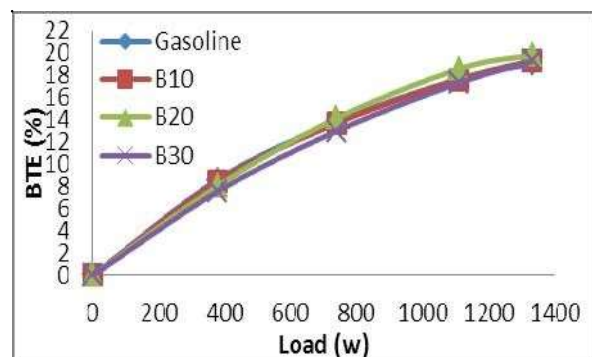
combustion but it is not satisfactory to overcome the effect of the lower calorific value thus only particular amount of alcohol is allowed to blend with gasoline without any modification. M30 blend shows you lowest thermal efficiency having lowest calorific value. Behavior of graphs plotted (Figure 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 E10 blends. 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



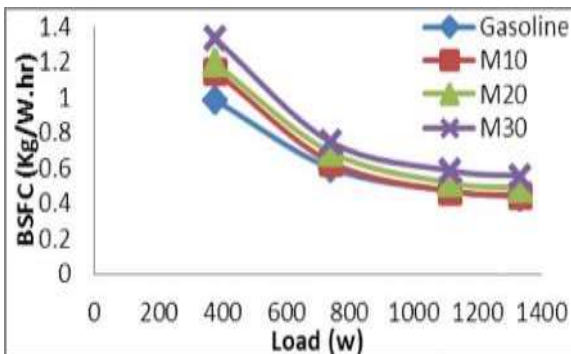
Brake Specific Fuel Consumption

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

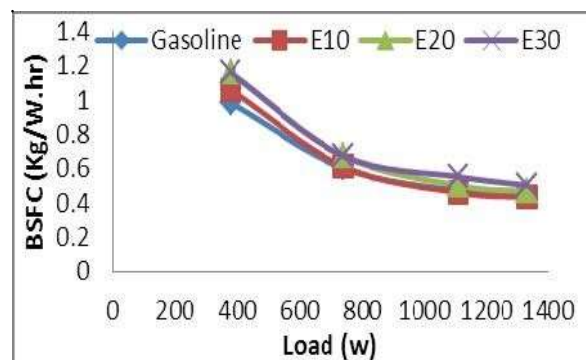
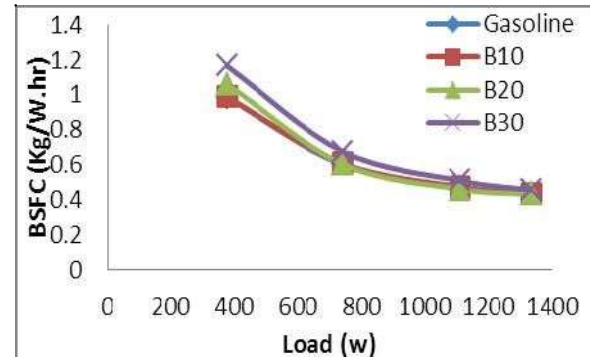


Figure 7: Brake Specific Fuel Consumption for Butanol Blends



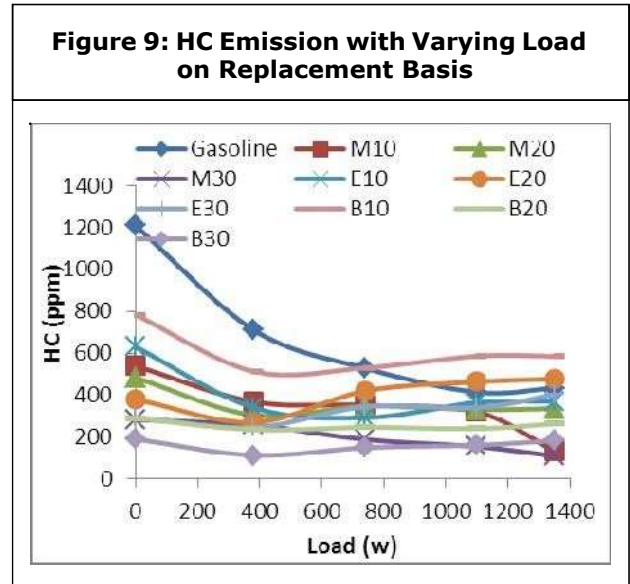
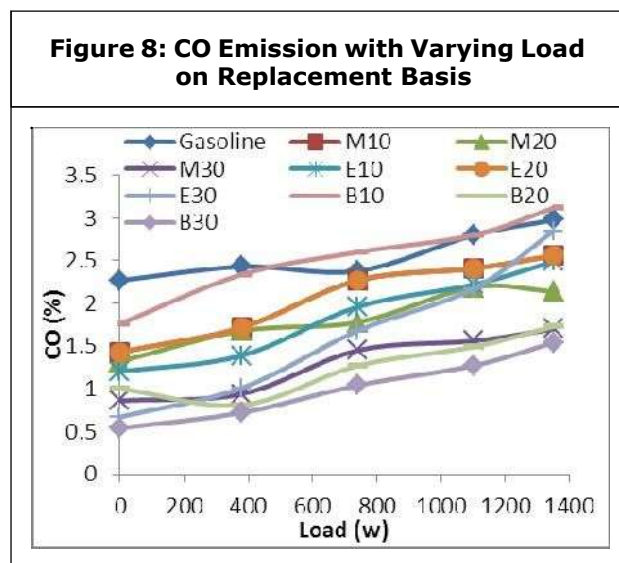
Emission of CO is unavoidable with available technology, since it is not possible to achieve supply of required air with proper mixing in combustion chamber which can sufficiently burn all fuel or even with higher air, the emission of carbon monoxide increase result of higher oxygen molecule.

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



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.

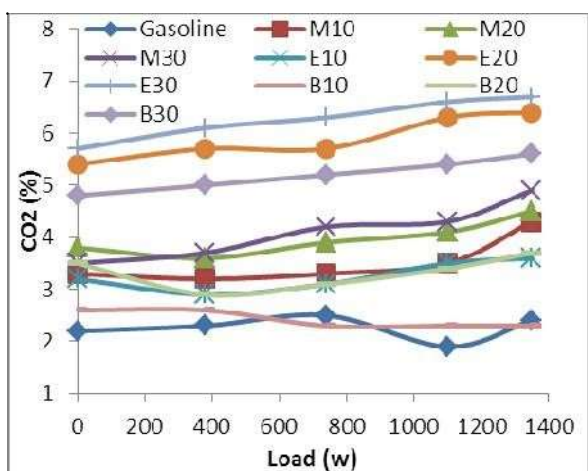
The graph plotted show least hydrocarbon emission for M30blend result of more oxygen and complete combustion. HC emission is also function of lean mixture and the setting was made to attain leaner mixture for better emission.

CO₂

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.

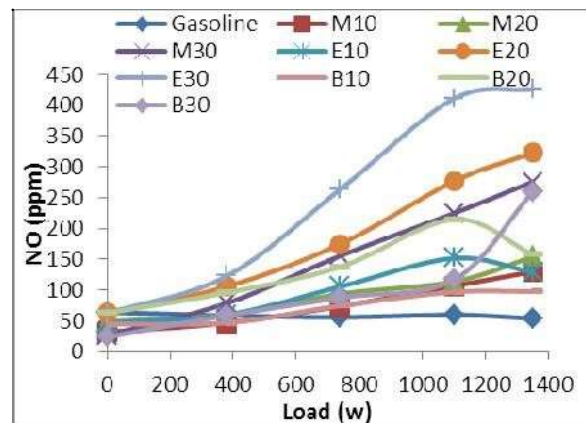
Figure 10: CO_2 Emission with Varying Load on Replacement Basis



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

Figure 11: NO Emission with Varying Load on Replacement Basis



shows increasing trend of NO for increase loading.

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

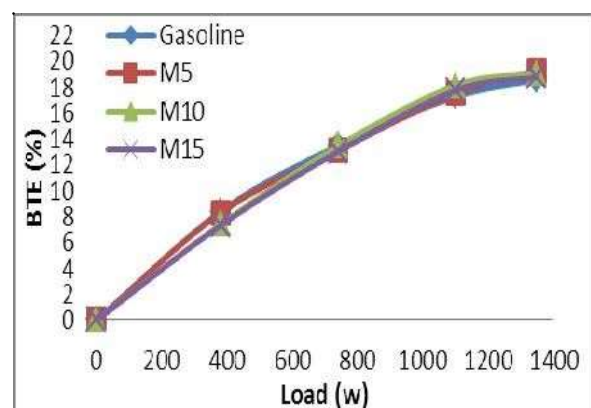


Figure 13: Brake Thermal Efficiency for Ethanol Blends of Oxygen Basis

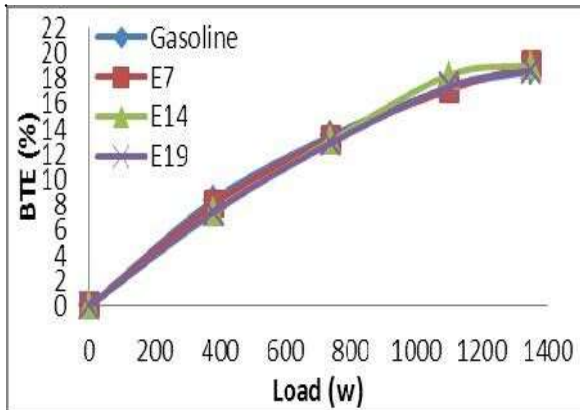


Figure 15: Brake Specific Fuel Consumption for Methanol Blends of Oxygen Basis

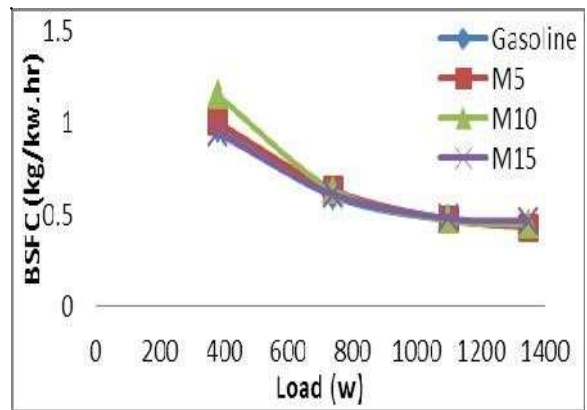
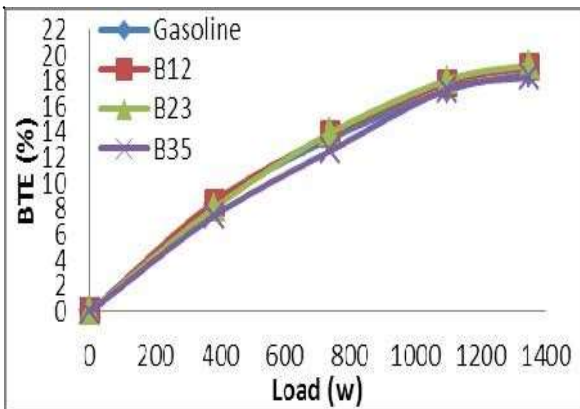


Figure 14: Brake Thermal Efficiency for Butanol Blends of Oxygen Basis



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.

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

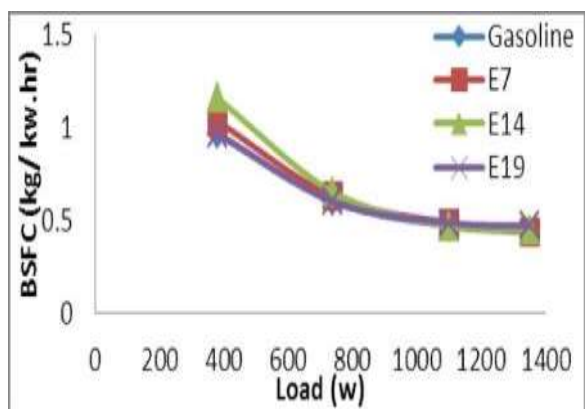
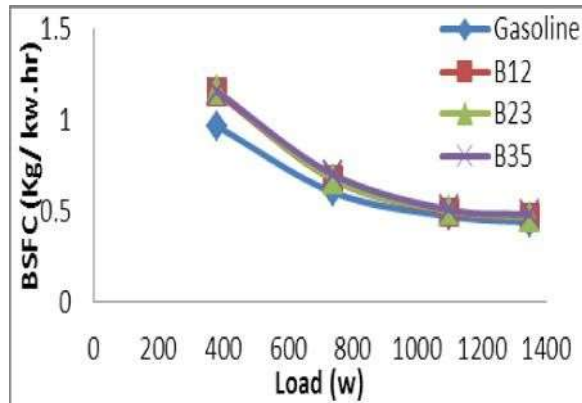


Figure 17: Brake Specific Fuel Consumption for Butanol Blends of Oxygen Basis



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

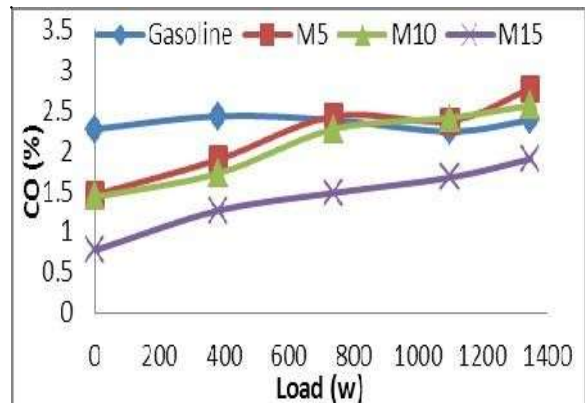


Figure 19: CO Emission for Blends of Ethanol Blends of Oxygen Basis

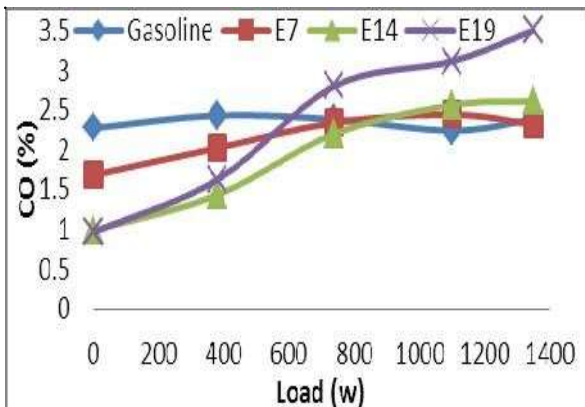


Figure 20: CO Emission for Blends of Butanol Blends of Oxygen Basis

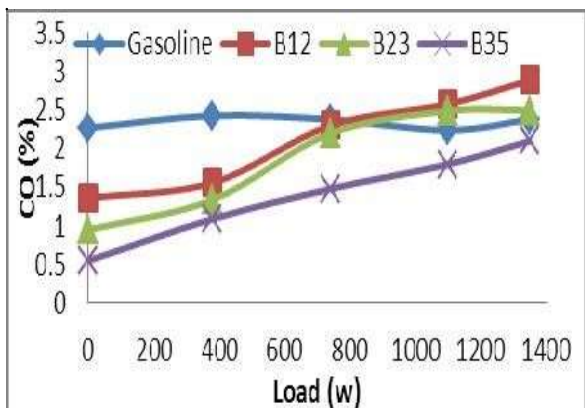


Figure 21: HC Emission for Blends of Methanol of Oxygen Basis

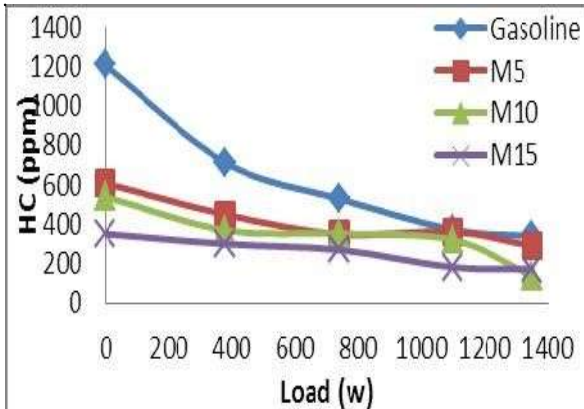


Figure 22: HC Emission for Blends of Ethanol of Oxygen Basis

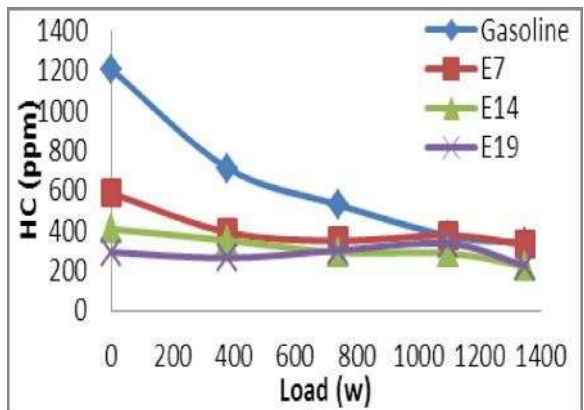
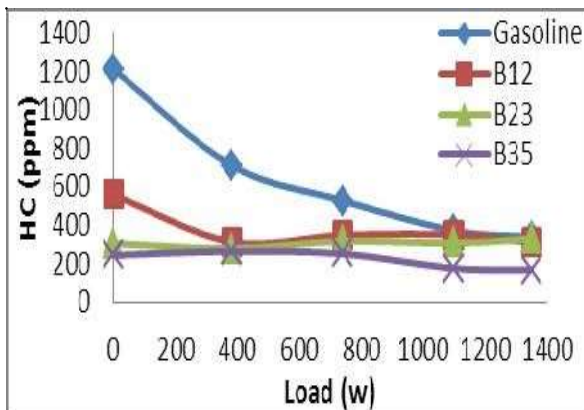


Figure 23: HC Emission for Blends of Butanol of Oxygen Basis



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.

CO₂

Emission of CO₂ 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: CO₂ Emission for Blends of Methanol of Oxygen Basis

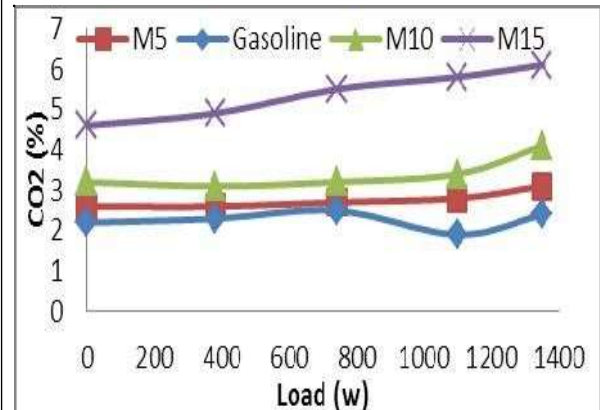


Figure 25: CO₂ Emission for Blends of Ethanol of Oxygen Basis

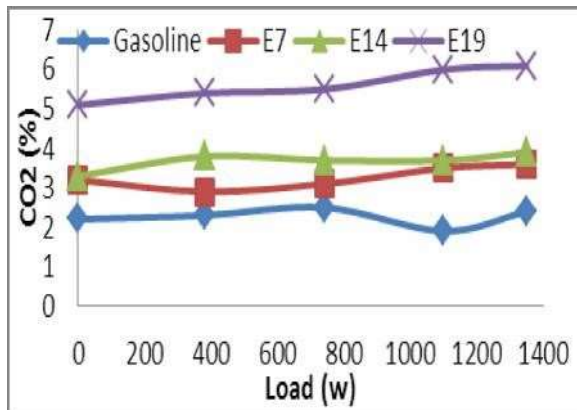


Figure 27: NO Emission for Blends of Methanol of Oxygen Basis

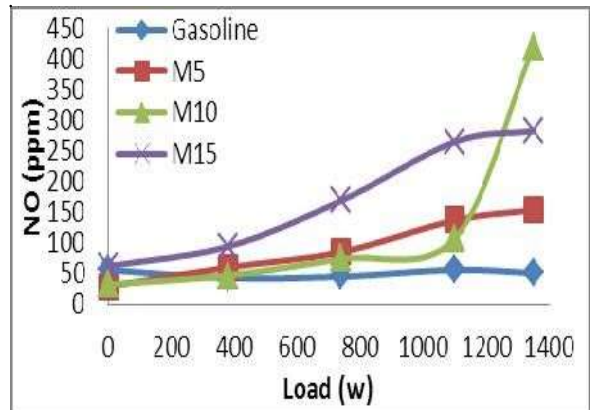


Figure 26: CO₂ Emission for Blends of Butanol of Oxygen Basis

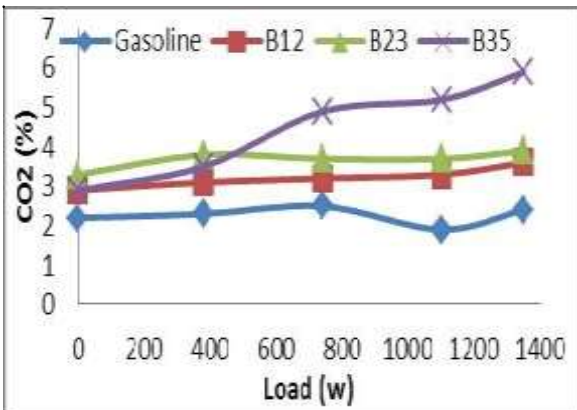
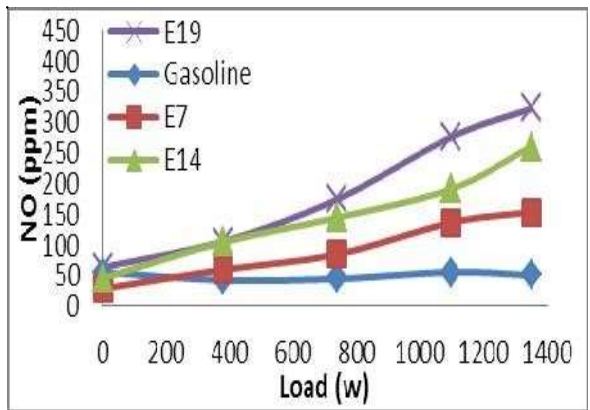


Figure 28: NO Emission for Blends of Butanol of Oxygen Basis



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

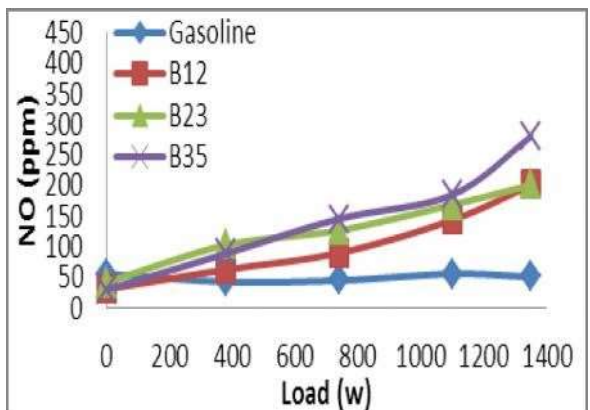
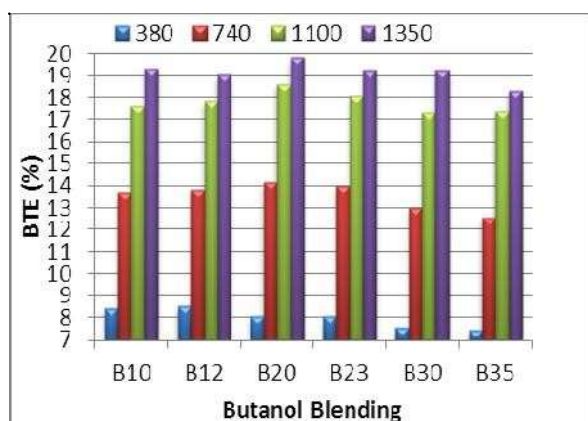


Figure 30: NO Emission for Blends of Ethanol of Oxygen Basis



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 brake 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 brake 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 CO₂ 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 CO₂ increases for 7.5% oxygen containing blend than 5% and 2.5% of oxygen contain. And CO, HC emission decreases.

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