International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 04 | Apr 2023 www.irjet.net p-ISSN: 2395-0072

Performance and Emission Analysis of Petrol Engine Fueled with Ethanol and Butanol Blended Gasoline Fuel

Hari Charan Chourasia[1], Alka Bani Agrawal[2]

[1]Student, Master of Engineering, Heat Power Engineering
[2]Professor and HOD, Automobile Engineering,
Department of Mechanical Engineering, University Institute of Technology,
Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, Madhya Pradesh, India- 462033

Abstract

Increasing population & continuous growth resulting the increasing number of vehicles and increasing demand of fuel leading the world towards the worst atmospheric conditions i.e. increasing pollution is one of the biggest problem through which most of the countries are struggling without having a significant solution. Increasing pollution & limited reserves for fossil fuel together with carbon emissions regulations have led to producing sustainable fuels made from renewable materials.

In recent years, the focus has been on using bio fuels as alternate energy sources. Blending bio-fuels with gasoline is one of the methods to be considered under the search for a new source of energy. Alcohols are an important category of bio-fuels. Butanol can be an alternative fuel since it is a liquid and has several physical and chemical properties similar to those of gasoline fuels. Butanol don't have many of the drawback associated with ethanol. Butanol has also a higher molecular weight than ethanol, and therefore, has reduced vapour pressure, lower water solubility, and higher energy density.

Keywords: *Alcohol, Ethanol, Butanol, Biofuel, Alternate fuel, Alcohol-Gasoline Blends.*

1. INTRODUCTION

Today's world is in the era of technology where a number of technological advancements are facilitating the modern world. Millions of inventions and their applications are upgraded a number of times and still in continuation by the research and development activities across the world but everything has its dark side as well. Among the enormous advantages of technology there are also a number of limitations that led to the world to face the critical problems related to technology and these problems if not meet to the solution, may become a great threat to the wellbeing and existence of a healthy society. One of the major problems associated with industry and automobiles is environmental pollution.

Increasing pollution & depletion of fossil fuel has led the interests of scholar to study about the reformulate of alternative fuel and after various researches after late 90's it has found that the blending of biofuel can be the best suited solution to this problem. According to previous study, the use of fuel alternatives that containing oxygen (oxygenates) was very important as the additive can increase the performance and efficiency of the fuel. Based on previous study, one of the best methods to improve the combustion behaviour is by blending base fuel with additives. Alcohol (Methanol, Ethanol, Butanol)-gasoline blends can reduce air pollution and at the same time offers excellent performance of the engine compared to unblended petroleum fuel . The effect of the alcohol gasoline blends on CO emissions for different engine speeds showed that when alcohol percentage increases, the CO concentration decreases. Carbon content in the blended fuel also plays a major part on the emission of CO due to the lower carbon content.

It has proven in many researches that alcohol reduces pollutant emission which resulted the use of alcohol specially ethanol for blending and as an alternative fuel. As the ethanol came in the practice it has found that it has its adverse effect i.e. corrosive effect on the engine materials and components due to that it cannot be used without engine modifications. Many government enforcing the regulatory to the automobile companies to manufacture engines with required modifications as they can withstand the corrosive effect of ethanol but still there is a large number of old vehicles are already in practice which cannot be made compatible for ethanol based fuel. Hence there is a requirement of an alternative fuel which can be used in the existing engines without modifications because modification and replacement of such a huge number of vehicles or engines is not practically possible. Many researchers have worked in this direction and butanol, which is also an isomer of alcohol, came into light. So, the present work is a comparative and competitive study of results to check the suitability of butanol over ethanol in order to find an alternative fuel for existing population of vehicles that cannot be modified to use ethanol based fuel. Under this study, experimental work has been done in which different

samples of ethanol and butanol blended fuel such as E10, E20, E30, B10, B20 & B30 has been tested on an older 2 stroke SI and their performance & emission characteristics have been compared.

2. MATERIALS AND METHODS

For this study, IOCL marketed gasoline was obtained from the City's filling station and fuel samples are prepared by mixing the alcohol with gasoline by volume percentage. Volume percentage of Ethanol and Butanol was kept from 10-30 percent by volume. Total six samples of blended fuel were prepared for the study. The ethanol fuel samples prepared by mixing 10%, 20% and 30% ethanol of 99.9% purity with gasoline by volume and these samples are named as E10, E20 and E30 respectively. Similarly, butanol fuel samples prepared by mixing 10%, 20% and 30% n-butanol of 99% purity with gasoline by volume and these samples are named as B10, B20, B30 respectively. In order to understand the behaviour of these blended fuel first of all we need to understand the properties of blended fuel.

After preparing the fuel samples it has been tested on a single cylinder two stroke petrol engine test rig at IC Engine Laboratory in Central Workshop under the department of Mechanical Engineering of University Institute of Technology, RGPV Bhopal (M.P.).

A schematic arrangements of various components of the experimental setup is shown in the figure 2.1. The important mechanical and electrical units involved in the testing are as follows:-

1. Two Stroke Petrol Engine
2. Fuel supply system with burette
3. Eddy Current Dynamometer
4. Dynamometer control unit
5. Digital Tachometer
6. Exhaust Gas Analyser with probe.

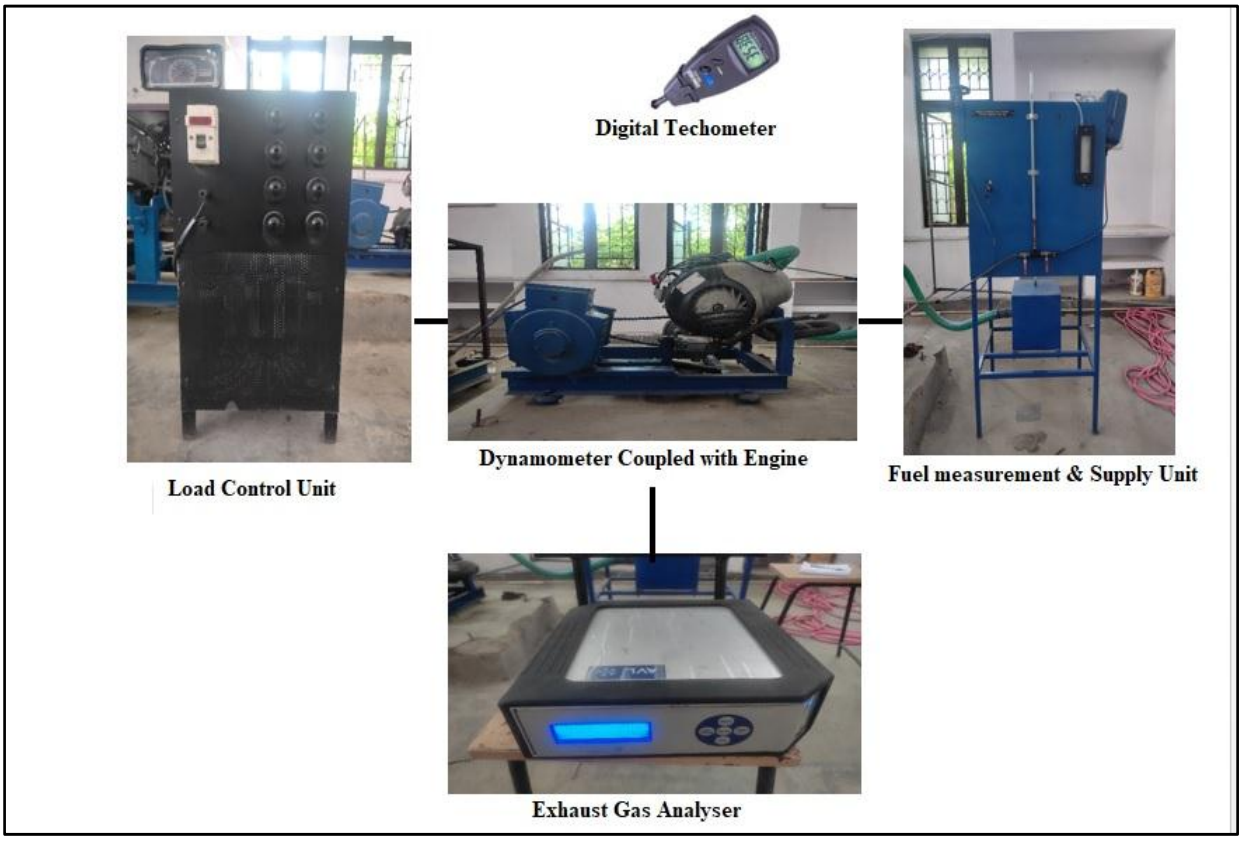

Fig. 2.1 *Experimental Set up*

As shown in the figure the fuel supply is connected to the carburettor of two stroke petrol engine with control valve by virtue of which the controlled volume of fuel is supplied to the engine. The engine shaft subjected to a chain drive which is connected to the Eddy current dynamometer. The applied load can be adjusted by a control unit connected with the dynamometer. The exhaust gas analyser with a sufficiently longer probe assembly is used to examine the exhaust from the engine. The actual arrangement of experimental is represented in the following figure.

After preparation of fuel samples, 100 ml. petrol is fed to the burette which is used to start and run the engine until the 100 ml fuel is consumed. In this idle running engine is lubricated properly and its components attains the working temperature. After idle running 100 ml. fresh gasoline is filled in the burette and adjustment of throttle is done until the engine achieves 1500 RPM which can be measured using a digital tachometer. The probe of exhaust gas is put inside the exhaust manifold for two minutes and the stable reading of exhaust gas analyzer is noted along with the time taken to consume 10 ml. fuel with the help of the stopwatch at zero load condition.

After getting the readings at zero load the load of 0.25 KW is applied by eddy current dynamometer with the help of dynamometer controller. Due to the application of load the speed of engine goes down which is adjusted by increasing the fuel supply using the throttle until the engine attains the speed of 1500 RPM again. Now again the probe of exhaust gas analyzer is put inside the exhaust manifold for two minutes and the stable reading of exhaust gas analyzer is noted along with the time taken to consume 10 ml. fuel with the help of the stopwatch.

The same procedure is repeated for 0.50 KW, 0.75 KW and 1 KW load and the readings of exhaust gas analyzer and stopwatch is noted for respective loads. The testing procedure for blended fuel samples is repeated in the same manner as followed for the testing of gasoline fuel sample and the reading for each fuel sample is noted carefully along with the fuel consumption time for 10 ml. fuel at no load and increasing load as 0.25 KW, 0.50 KW, 0.75 KW and 1.0 KW respectively. The value of Brake Thermal Efficiencies (BTE) and BSFC for each fuel is calculated using mathematical relations after calculating the properties of blended fuel samples whereas, the values of pollutant emission obtained directly from the readings of exhaust gas analyser.

3. RESULTS AND DISCUSSION

As per experimental results obtained for various fuels, the comparison of performance and emission characteristics of Gasoline, E10, E20, E30 & B10, B20, and B30 can be done in order to identify the suitable fuel blend that can be used in existing SI engines without any modification.

3.1 Comparison of Performance Characteristics: - The comparison of performance characteristics i.e. Brake Thermal Efficiency (BTE) and Brake specific fuel consumption (BSFC) is shown on the basis of experimental results which is briefly discussed as follows.

3.1.1 Brake Thermal Efficiency (BTE):- The comparison of brake thermal efficiency of all fuels is represented with the help of following figure

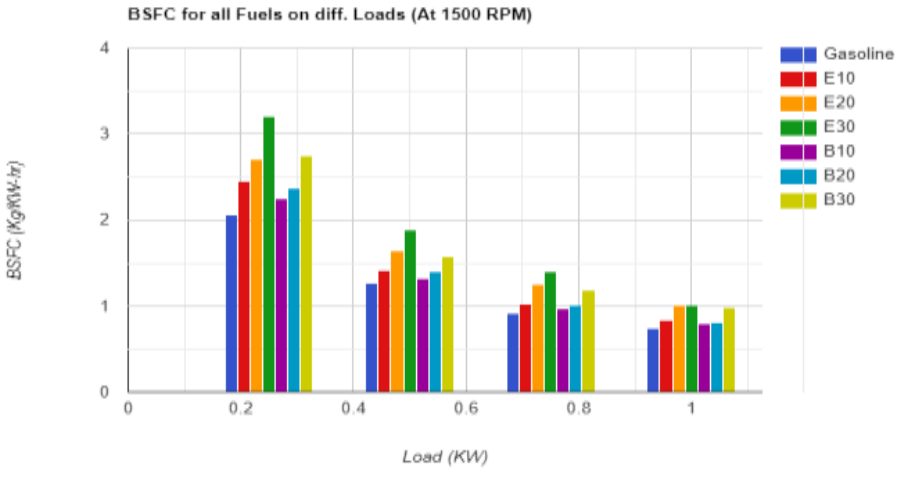

Fig. 3.1 *Brake Thermal Efficiencies for all fuel samples at diff. Load*

As shown in the above figure it is clear that brake thermal efficiency of fuel blends is lower as compared to pure gasoline. The reason of lower brake thermal efficiency is nothing but the lower calorific value of alcohol as compared to gasoline. As per experimental results, brake thermal efficiency decreases with increasing percentage of alcohol in the blend because alcohol has lower calorific value as compared to gasoline. It can also be seen that brake thermal efficiency of butanol blends is slightly higher than that of ethanol blends because butanol contains comparatively higher energy content per unit volume and lower heat of vaporization as compared to ethanol. Brake Thermal Efficiency is observed as highest for B10 among all fuel blends due to the optimum parameters i.e. balance between lower calorific value and higher volumetric energy content.

3.1.2 Brake Specific Fuel Consumption (BSFC):-The comparison of brake thermal efficiency of all fuels is represented with the help of following figure:-

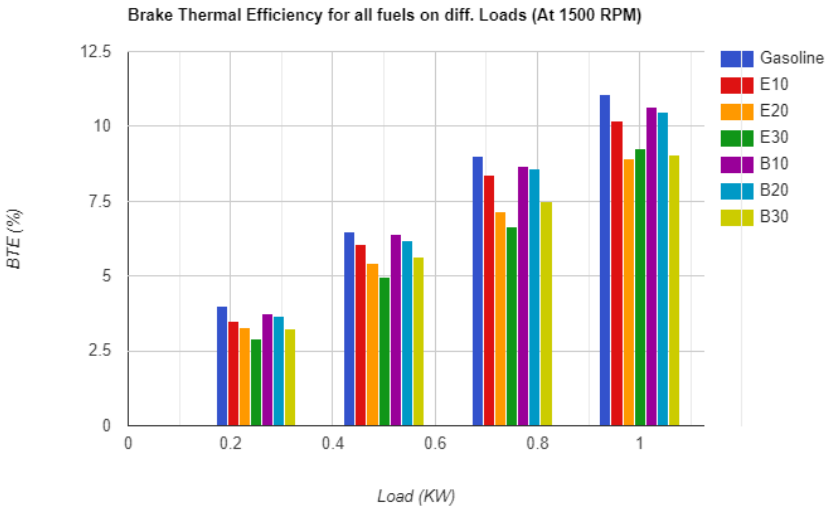

Fig. 3.2 *BSFC for all samples at diff. Loads*

As shown in the above figure it is clear that BSFC for fuel blends is higher as compared to pure gasoline. The reason of higher BSFC is nothing but the lower calorific value of alcohol as compared to gasoline. As per experimental results, BSFC increases with increasing percentage of alcohol in the blend because alcohol has lower calorific value as compared to gasoline. It can also be seen that BSFC of butanol blends is slightly lesser than that of ethanol blends because butanol contains comparatively higher energy content per unit volume and lower heat of vaporization as compared to ethanol. BSFC is observed as lowest for B10 among all fuel blends due to the optimum parameters i.e. balance between lower calorific value and higher volumetric energy content.

3.2 Comparison of Emission Characteristics: - The comparison of main pollutants i.e. HC, CO and NO_x from the various fuel sample is done on the basis of experimental results which can be understand as follows.

3.2.1 Hydrocarbon (HC) Emission: - As per the results obtained for unburnt hydrocarbon emission the comparison of HC emission for various fuels can be understand with the help of following figures. On the basis of above comparison the following observations can be made:

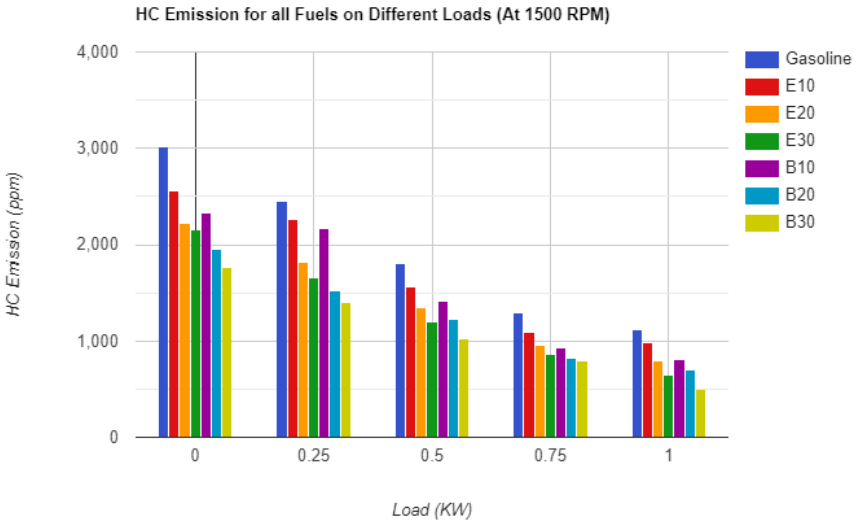

Fig. 3.3 *HC Emission for all fuel samples at diff. Loads*

The HC Emission for fuel blends is lower than pure gasoline. The reason of lower HC emission for alcohol fuel blends is the presence of oxygen molecules in the alcohol which aids to the better combustion of fuel whereas no oxygen is present in gasoline. As the alcohol percentage increases in the fuel, unburnt hydrocarbon emission decreases because the amount of oxygen is also increases with alcohol which leans the air fuel mixture and results for better combustion of fuel. Hydrocarbon Emission for Butanol blends is found lower as compared to Ethanol blends. The reason behind the lesser HC emission of butanol is the lower heat of vaporization and higher calorific value as compared to ethanol due to that butanol blends burns more efficiently as compared to ethanol blends Hence better combustion results decrease in unburnt hydrocarbon particles. Hydrocarbon Emission is found minimum for B30. It is because of the higher percentage of butanol which results better combustion than that of other fuel blends.

3.2.2 Carbon Mono-Oxide (CO) :- As per the results obtained for carbon mono oxide emission, the comparison of CO emissions for various fuels can be understand with the help of following figures:-

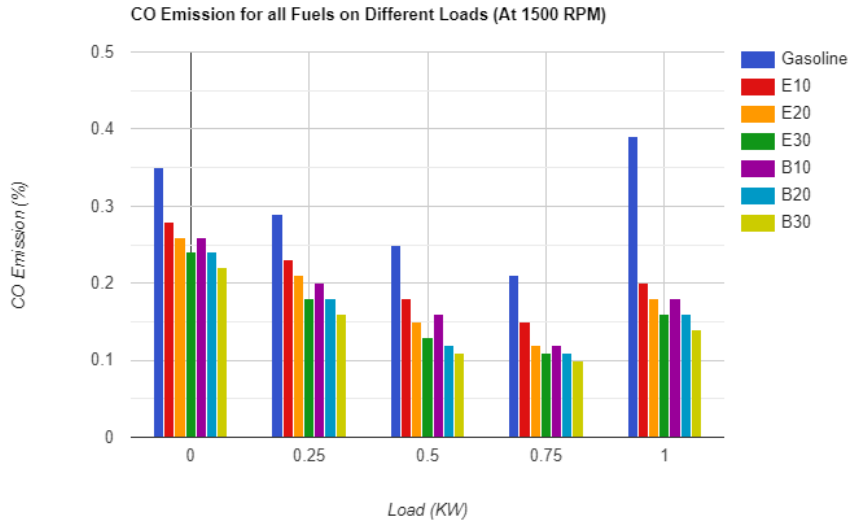

Fig. 3.4 *CO Emission for all fuel samples at diff. Load*

The CO Emission for fuel blends is lower than pure gasoline. The reason of lower CO emission for alcohol fuel blends is the presence of oxygen molecules in the alcohol which aids to the better combustion of fuel whereas no oxygen is present in gasoline. As the alcohol percentage increases in the fuel, CO emission decreases up to a certain value of load due to oxygen rich burning and then increases because increasing load requires more power rapidly but as alcohols have comparatively lower calorific value and higher vapour pressure than gasoline therefore, gasoline molecules burns faster in order to fulfil the energy demand and a slight delay is observed in burning of alcohol molecules as compared to gasoline which results heterogeneous burning of fuel blend and result increase in CO emission. CO for butanol blends is found lower as compared to Ethanol blends. The reason behind the lesser CO emission of butanol is the lower heat of vaporization and higher calorific value as compared to ethanol due to that butanol blends burns with high temperature as compared to ethanol blends Hence better combustion results decrease in unburnt hydrocarbon particles. Hydrocarbon Emission is found minimum for B30. It is because of the higher percentage of butanol which results better combustion than that of other fuel blends.

3.2.3 NO_x Emission: - As per the results obtained for unburnt hydrocarbon emission the comparison of NOx emission for various fuels can be understand with the help of following figures.

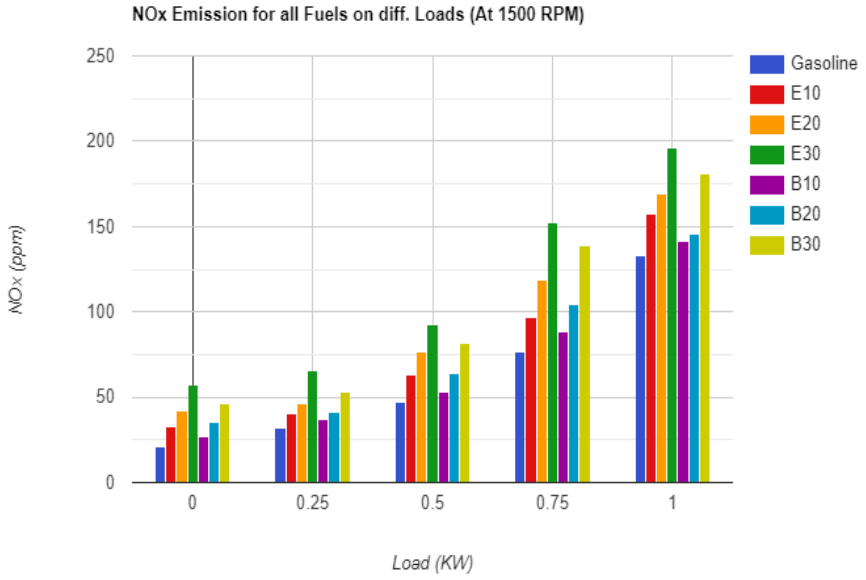

Fig. 3.5 *NOx Emission for all fuel samples at diff. Loads*

The NO_X Emission for fuel blends is higher than pure gasoline. The reason of higher NO_X emission for alcohol fuel blends is the presence of oxygen molecules in the alcohol which aids to the better combustion and results increase in cylinder temperatures which gives rise to the formation of NO_X in the combustion products. As the alcohol percentage increases in the fuel, NO_X emission decreases because the amount of oxygen is also increases with alcohol which leans the air fuel mixture and results for better combustion of fuel and increase of in cylinder temperature. NO_X Emission for butanol blends is found lower as compared to Ethanol blends. The reason behind the lesser NO_X emission of butanol is the lower amount of oxygen present in the atomic structure as compared to ethanol. Ethanol consists of 34.78% oxygen whereas butanol consists of 21.62% oxygen by weight due to which ethanol burns with comparatively high temperature than that of butanol and leads to the formation of more NO_X in the exhaust. Hydrocarbon Emission is found minimum for B10. It is because of the balance between the higher calorific value and lower amount of oxygen as compared to ethanol blends which results the burning of fuel at optimum temperature

4. CONCLUSION:-

On the basis of experimental results obtained it can be concluded that the Brake Thermal Efficiency of fuel blends is slightly lower as compared to the pure gasoline because of the lower calorific value and higher heat of vaporization of alcohols. If we compare individual blended fuel samples, butanol blends shows comparatively higher brake thermal efficiency than ethanol blends which is because of higher calorific value and lower heat of vaporization of butanol as compared to ethanol whereas B10 is the sample identified with maximum efficiency. The Specific fuel consumption is higher for gasoline-alcohol blends as compared to pure gasoline which is because of lower calorific value and higher heat of vaporization of alcohols which represent that the fuel consumption will be more for gasoline- alcohol blends as compared to pure gasoline. If we compare the BSFC of ethanol and butanol blends it is found lower for butanol blends and minimum for B10 due to its higher energy content which represent that butanol blended fuel is more economic than ethanol blended fuel.

If we discuss emission characteristics so it has found that the HC and CO Emission for fuel blends is lower than pure gasoline. The reason of lower HC & CO emission for alcohol fuel blends is the presence of oxygen molecules in the alcohol which aids to the better combustion of fuel whereas no oxygen is present in gasoline. HC & CO Emission for butanol blends is found lower as compared to Ethanol blends. The reason behind the lesser emission of butanol is the lower heat of vaporization and higher calorific value as compared to ethanol due to that butanol blends burns more efficiently as compared to ethanol blends Hence better combustion results decrease in unburnt hydrocarbon particles. On the other hand the NO_X Emission for fuel blends is higher than pure gasoline. The reason of higher NO_X emission for alcohol fuel blends is the presence of oxygen molecules in the alcohol which aids to the better combustion and results increase in cylinder temperatures which gives rise to the formation of NO_X in the combustion products. NO_X Emission for butanol blends is found lower as compared to Ethanol blends. The reason behind the lesser NO_X emission of butanol is the lower amount of oxygen present in the atomic structure as compared to ethanol. Ethanol consists of 34.78% oxygen whereas butanol consists of 21.62% oxygen by weight due to which ethanol burns with comparatively high temperature than that of butanol and leads to the formation of more NO_X in the exhaust.

The implementation of butanol blending may be a better alternative to reduce pollutants emission from existing older SI engines while ethanol is suitable for the new generation SI engines or existing engine with modifications. As a large number of vehicles are not possible to modify or replace with the new therefore, butanol blending can play a vital role to control the increasing pollution of the fossil fuels and can also save the petroleum using this green fuel.

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