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Potential use of bio- ethanol performance on variable compression ratio petrol engine

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Abstract

India is among the world's fastest growing economies. The demand for crude oil and petroleum products is high and increasing. Fossil fuels have traditionally served as the primary energy source for the transportation industry. Biofuels, on the other hand, have recently acquired popularity as realistic replacements with significant economic and environmental benefits. In terms of energy usage, India comes in third place worldwide. India's fuel ethanol initiative is largely motivated by two objectives: lowering emissions and reducing dependency on fossil fuels. Petroleum provides the vast majority of the world's energy. Growing energy use and overreliance on imports raise serious worries about energy security. Its Energy demands are mostly satisfied by oil, which it continues to buy in large amounts from other nations. India will have doubled its energy consumption by 2050. Increased energy use and reliance on imports pose a severe threat to energy security. Furthermore, it results in a massive outflow of foreign exchange. A 4.75 kW gasoline engine with a variable compression ratio that was in sync with IC Engine software 9.0 was used for the testing in order to assess the feasibility of employing bioethanol blends. The blends were created on a volume basis in the following proportions: 05:95, 10:90, 15:85, 20:80, 25:75, and 30:70. They were referred to as E5, E10, E15, E20, E25, and E30 in comparison to gasoline E0. The findings indicate that bioethanol may be mixed with petrol up to E20 without requiring engine modifications, However, large percentage of biethanol combinations will not perform properly. . The emission parameters of the E20 bioethanol mix have produced good results and met emission standards out of all the blends studied. Developing nations like India may have the raw materials required to enhance bioethanol production. A higher minimum support price for sugarcane harvest benefits farmers economically.

1. Introduction

India's energy needs are rapidly expanding. In answer to the transportation industry's need, bioethanol may now be added to vehicle fuels in the present world [1]. Following regulatory actions, gasoline is expected to have a 10% ethanol blend target by 2022 and a 20% ethanol blend target by 2030. In this densely populated country, finding a balance between using land for food production and using land for biofuel crops is a major challenge. In 2001, India started an experimental demonstration programme for ethanol-in-petrol [2].

Petroleum is the single largest source of energy consumed by the world's population. Growth in the world's demand for oil is expected to slow in the coming years as energy transitions advance.Despite the slowdown in growth, global oil demand is still forecast to be 3.2 million barrels per day higher in 2030 than in 2023 unless stronger policy measures are implemented or changes in behaviour take hold [3]. One of the significant way to overcome the problem of increasing prices and pollution problems of petroleum fuels in future is the use of green fuels such as bio- ethanol. India's need for energy is growing very quickly. Adding bioethanol [4] to vehicle fuels became possible in 2003 in response to demand from the transportation industry. Subsequent policy [5] initiatives have yielded a 10% ethanol blend objective by 2022 and a 20% ethanol blend aim by 2030 for gasoline.

India is a biomass-rich country and the second-largest sugarcane producer in the world. Therefore in developing countries including India, there is a potential availability of raw material [1] for increase the production of bio ethanol [6]. It Supports the farmer economy to get more MSP (Minimum Support Price) for their sugarcane crop . The sugar industry is an instrumental in generating the sizable employment in the rural sector directly and also through its ancillary units manufacturing bio ethanol and other useful products. In order to reduce environmental pollution, bioethanol is required as a renewable fuel with lower emissions and comparable costs. High H/C (hydrogen/carbon) ratios, higher oxygen content, and ethanol's low molecular weight cause it to burn completely when exposed to oxygen. India is one of the fastest growing economy in the world, continues to experience a high and increasing demand of crude oil and petroleum products, Traditionally fossil fuels have been the primary source of energy in the transportation sector. The share of fossil fuels in global energy supply, which has been stuck for decades at around 80%, declines to 73% by 2030, with global energy-related carbon dioxide emissions peaking by 2025.

Alfredas Rimkus et al [7] conducted a research experiment on performance and emission parameters of various bioethanol blend ranging from E0 to E70. As the concentration of bioethanol blend is increased with fuel the brake torque & brake mean effective pressure consistently increases up to 1.7%. The brake specific fuel consumption was moderately increased with increase in bioethanol blend due to higher density of bioethanol [8] compared with gasoline. This study reveals that there is no linear relationship between the enhancement in brake thermal efficiency and the amount of bioethanol, small amount of bioethanol is enough to improve brake thermal efficiency. If further increase in amount have smaller effect. If engine runs on lean mixture a certain amount of bioethanol significantly enhances the operating efficiency.

Carbon dioxide emissions fall by 1.1% as the concentration of bioethanol steadily rises. The amount of carbon monoxide produced and the blend's bioethanol content was shown to be inversely correlated. Hydrocarbon emissions show a notable 8.2 percent drop with an increase in bioethanol content. In every studied situation, the addition of bioethanol reliably lowers nitrogen oxide emissions. This experimental study shown that raising the amount of bioethanol in gasoline greatly enhances the engine's environmental performance. Optimizing the engine parameter for increased efficiency is difficult, and further study is needed to improve the mix ratio. Therefore, an effort was undertaken to look into the emission characteristics and engine performance of bioethanol combined with gasoline.

In the review paper Minal Deshmukh et al [9] referred around ninety research papers and concluded with following observations.The blending of bioethanol enhances the physicochemical properties which in turn improves the engine performance. The advancement of bioethanol improves the combustion and decreases the duration of combustion. The blending of bioethanol with petrol leads to fluctuations in brake power. Brake specific fuel consumption drastically reduces for 40% bioethanol blend. The mechanical efficiency increases by increasing bioethanol blending. It is observed that each 5% increase in bioethanol blend decreases about 6% emission of unburnt hydro carbons. The increase in bioethanol blend concentration nitrogen oxide emission level of engine decreases due to lower heating value and higher latent heat of vaporization in bioethanol gasoline blends. The performance parameters depend on quality, operating conditions and engine specifications. Also, it can be studied that blending of bioethanol with gasoline is more significant than with diesel blending, with mostly 4 stroke engines with various range of following operating parameters. Power requirement is 4.5 kilo watt at 1800 rpm Speed , Compression ratio 6:1 to 10:1 Therefore, this research is needed to optimize blending bioethanol with engine performance.

The experimentation is carried out for bioethanol blend ranging from E0, E10, E20, E25 and examined with gasoline. It is noticed that total fuel consumption in gasoline is little high compared with ethanol blend. The percentage of bioethanol blend increases the indicated thermal efficiency, brake thermal efficiency and mechanical efficiency [10]. The performance of the engine comparatively decreased for E25 blend. It clearly indicates that further addition of ethanol will reduce the engine performance severely. This experiment reveals that improved performance is obtained by adding the bioethanol with gasoline at certain percentage as ethanol gasoline blend. This concluding remarks will instigate to carry out this research work to optimize the blend ratio for better engine efficiency.

The amount of ethanol India has on hand has grown by more than six times in the last seven years, reaching 4,336 million litters. The nation has now advanced its 20% ethanol blending target from 2025 to 2030. It accomplished the milestone of a 10% ethanol blending rate five months ahead of schedule. It has also established a goal of blending bioethanol at a rate of 25% by the year 2030. This will instigate to conduct a Research Experiment on Bioethanol blended with Petrol on variable compression ratio engine for various blends and Compression Ratios. The results and effect of bioethanol on various blends at different compression ratios are discussed elaborately in further sections [1].

Table 1. Description of bioethanol blend samples.

Blend sample	Description	Abbreviation
Sample 1	100% pure petrol	E0
Sample 2	5% bioethanol + 95% petrol	E5
Sample 3	10% bioethanol + 90% petrol	E10
Sample 4	15% bioethanol + 85% petrol	E15
Sample 5	20% bioethanol +80% petrol	E20
Sample 6	25% bioethanol + 75% petrol	E25
Sample 7	30% bioethanol + 70% petrol	E30

The study may help the country to reduce their dependence on oil-producing countries and strengthen their energy security. [3] Outcome of the result helps sugarcane and ancillary industries to be self sufficient and the sugarcane growing farmer may get higher economic return.The significance of the research work will focus on the economy of the country, India has saved foreign cash as a result of the corresponding decrease in the import of crude oil and gasoline brought about by the production of ethanol. With an estimated 5020 million litres of ethanol produced in 2022–2023, India increased its energy security and saved roughly 243 billion in foreign exchange.

A sustainable and renewable alternative fuel, [11] biofuel is primarily made from recycled greases (used cooking and frying oils), plant oils (from soybeans, corn, rapeseed, sunflowers, and cottonseeds, etc), and animal fats (tallow, lard, white or yellow grease, poultry fats, or fish oils). Additionally, no modifications to the engine are required to use this biofuel in diesel engines. Biofuel is an umbrella word for a wide variety of transportation fuels [12] made mostly from biomass, including both liquid and gaseous forms. One crucial link in the biofuel production cycle is the biofuels conversion system. Promoting biofuels' future [13] competitiveness versus fossil fuels in the market requires factors like low energy consumption and high yields.

Petroleum is the single largest source of energy consumed by the world's population. Growth in the world's demand for oil is expected to slow in the coming years as energy transitions advance. Despite the slowdown in growth, global oil demand is still forecast to be 3.2 million barrels per day higher in 2030 than in 2023 unless stronger policy measures are implemented.

Ethanol blended fuel may have lesser nitrogen oxide emission and comparably cheaper alternative fuel [14] to reduce environmental pollution. Bioethanol produces less carbon dioxide than fossil fuels [15], and the carbon dioxide it does produce can be captured and used in other industries. Bioethanol is a renewable energy source that comes from biomass [16], grown using energy from the sun and reduce their dependence on oil-producing countries. Bioethanol has a higher density than petrol, which can allow more fuel to be sprayed into the cylinder. Demand for bioethanol creates jobs in the agricultural sector [17] and at bioethanol plants. Outcome of the result helps sugarcane and ancillary industries to be self-sufficient, the sugarcane growing farmer may get higher economic return. Research into using ethanol blends as fuel in variable compression ratio gasoline engines has shown that higher compression ratios lead to more efficient use of the brakes. The brake thermal efficiency is greater than other mixes when 20% ethanol is added to petrol.

2. Methodology

One of the significant routes to tackle the problem of increasing prices and pollution problems of petroleum fuels in future is the use of green fuels such as bio- ethanol. Ethyl Alcohol commonly called as Ethanol is a renewable fuels with lesser emission and comparably cheaper are required as an alternative [18] to reduce environmental pollution. Ethanol is having larger oxygen content, low molecular weight, and high hydrogen to carbon ratios and can burn completely with oxygen.

India is one of the fastest growing economies in the world, continues to experience a high and increasing demand of crude oil and petroleum products traditionally fossil fuels have been the primary source of energy in the transportation sector. The share of fossil fuels in global energy supply, which has been stuck for decades at around 80%, declines to 73% by 2030.

The bioethanol blend samples are prepared [19] and abbreviation details are recorded in table 1. Now onwards these abbreviation of bioethanol blend samples are considered in the present research work in further section.

A single-cylinder, four-stroke, air-cooled, spark-ignition, gasoline-powered engine makes up the test rig. An eddy current dynamometer is employed to assess the performance of the engine. A fuel measurement system, air intake tank, cooling water flow rate gauge, and temperature monitoring devices are all part of the test setup. A separate control panel, unrelated to the engine unit, contains all measurement instruments. To adjust the

Table 2. Physico chemical properties of bioethanol blends.

Physico chemical properties	ASTM	E0	E5	E10	E15	E20	E25	E30
Density Kg/m^3	D287	723	728	732	736	741	746	749
Calorific value Cal /gm-°C	D4809	10550	10493	10335	9877	9690	9385	9205
Flash Point °C	D9358T	−42	−37	−30	−26	−21	−16	−8
Fire Point °C	D9358T	−42	−37	−30	−26	−21	−16	−8
Kinematic Viscosity cSt	D445	0.9	1.01	1.04	1.07	1.1	1.14	1.16
Dynamic Viscosity cP	D445	0.65	0.74	0.76	0.79	0.82	0.85	0.87

Table 3. Specifications of research petrol engine.

Sl no	Engine parameters	Details
1	Power	4.5 KW
2	Max Speed	1800 rpm
3	Cylinder bore	87.5 mm
4	Stroke length	110 mm
5	Compression Ratio	10
6	Swept Volume	661.5 cc
7	Stroke type	Four
8	Number of cylinder	One
9	Cooling Type	Water
10	Fuel Type	Petrol
11	Compression type	VCR
12	Engine Name	Kirloskar TV1

compression ratio, a hand wheel and indicator are mounted on the auxiliary cylinder, which has a piston that is located above the main cylinder head.

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Research engine connected to eddy current dynamometer. It is provided with necessary instruments for combustion pressure, crank angle, airflow, fuel flow, temperatures and load measurements. These signals are interfaced to computer through high speed data acquisition device. The set up has stand-alone panel box consisting of air box, twin fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo powering unit. Rotameters are provided for cooling water and calorimeter water flow measurement. In petrol mode engine works with programmable Open Electronics Circuit Unit, Throttle position sensor , fuel pump, ignition coil, fuel spray nozzle, trigger sensor etc The setup enables study of VCR [20] engine performance for both Diesel and Petrol mode and study of Electronics Circuit Unit programming. Engine performance study includes brake power, indicated power, frictional power, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, Air fuel ratio, heat balance and combustion analysis.

In this section the preparation of bio ethanol blend samples, the method for testing physico –chemical properties [21] of each sample, research engine specification, experimental setup and test procedure are discussed thoroughly. The bioethanol blend samples are prepared and abbreviation details are recorded in table 1. Now onwards these abbreviation of bioethanol blend samples are considered in the present research work in further section. The physico chemical properties [22] are tested as per ASTM standard and test procedure is explained in this section. The tested values are tabulated and recorded in table 2.

The tank is filled with a blend of gasoline and biofuel. Make sure there is sufficient circulation of lubricating oil and cooling water before starting the test rig. Turn the hand wheel to the desired compression ratio and secure it. Once the engine has stabilized at its rated speed, start the test rig. Fuel usage and manometer readings under no load situations should be recorded first. To stabilize all starting conditions, the engine was let to run for 15 min on pure gasoline. Following the completion of the experiment, five replications of each blend were tested for each set including compression ratio. The specification of engine used for the research work is presented in table 3.

Once the trials with each blend at compression ratio were finished, the given enough time to run in order to use up the whole fuel sample measured in the manometer. For each set of readings, the same process is carried out. Following established protocol and utilizing the data collected, the performance characteristics were calculated. Subsequent sections will address the comparison of findings with gasoline.

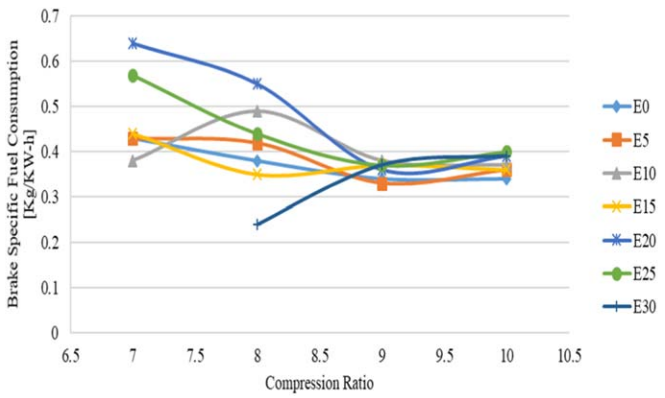

Figure 1. Brake specific fuel consumption versus compression ratio.

The overall flammability and quality of selected blends were analysed by determining various physical and chemical properties [23] as per ASTM standard procedures [24]. The density of the fuel was determined by pycnometer. The kinematic viscosity of the test fuels was determined by using a constant temperature bath Redwood viscometer. An adiabatic oxygen bomb calorimeter was used to determine the calorific value of the fuels [25]. The Pensky Marten's open cup flash and fire point apparatus was used to the determine flash and fire points of the selected blends of bioethanol and petrol

A single-cylinder, four-stroke, air-cooled, spark-ignition, gasoline-powered engine makes up the test rig. An eddy current dynamometer is employed to assess the performance of the engine. A fuelmeasurement system, air intake tank, cooling water flow rate gauge, and temperaturemonitoring devices are all part of the test setup. A separate control panel, unrelated tothe engine unit, contains all measurement instruments. To adjust the compression ratio [26], a hand wheel and indicator are mounted on the auxiliary cylinder, which has a piston that is located above the main cylinder head.

The variac knob, which is fixed on the control panel for the eddy current dynamometer, allows the load to be changed from zero to full load. By turning the knob, you may alter the compression ratio for a certain position. Various measurements for instance the fuel mass flow rate (manometer input). On the dashboard, you can see the current engine speed, air intake temperature, and exhaust temperature. Three different compression ratios (7, 8, 9 and 10) were tested using 100% gasoline in the studies. The Research petrol Engine is synchronized with IC Engine Soft V 9.0 and all the performance data were tabulated using the interface of this software.

3. Results & discussion

This section revealed the acquired results from experimental testing of Petrol engine fueled with different blends of bio ethanol with petrol.

3.1. Fuel properties

The kinematic viscosity and specific gravity of all the selected blends found to be higher than that of petrol, it was maximum for E30 among the selected blends (E0, E05, E10, E15, E20, E25, and E30).The calorific value of E30 blend was found to be 37.42 MJ Kg that was 11.08 per cent lesser than the calorific value of petrol (42.43 MJ Kg). As the percentage of bioethanol in the blends increased, the calorific value decreased which may be due the presence of more oxygen molecules [27]

3.2. Performance of engine

The performance of the IC engine [28] is tested with pure gasoline and ethanol blends. The degree of success is compared [29] on the basis of specific fuel consumption, Brake mean effective pressure, specific power output, specific weight and Exhaust smoke and other emissions.

The results of comparing the brake-specific fuel consumption [30] of each blend at various compression ratios revealed that the 20% bioethanol blend was comparable to and compatible with pure gasoline. Figure 1 shows the brake specific fuel consumption and compression ratio graphs. From figure 1, we can see that as compression ratio increases, the brake specific fuel consumption of all the tested blends drops beyond compression ratio at 7. This suggests that the engine may have banging issues at higher compression ratio levels. Fuel consumption is constant across all ethanol mixes up to a compression ratio of 7.

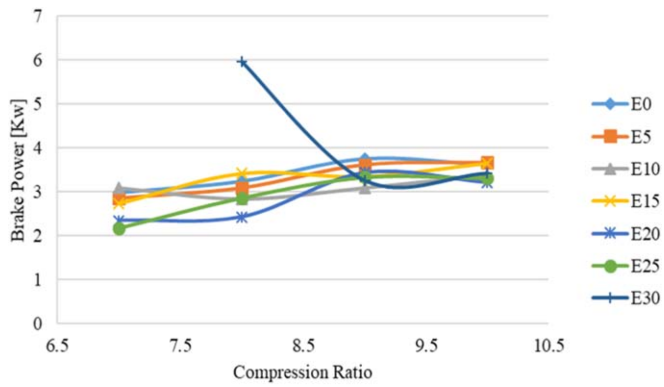

Figure 2. Brake power versus compression ratio.

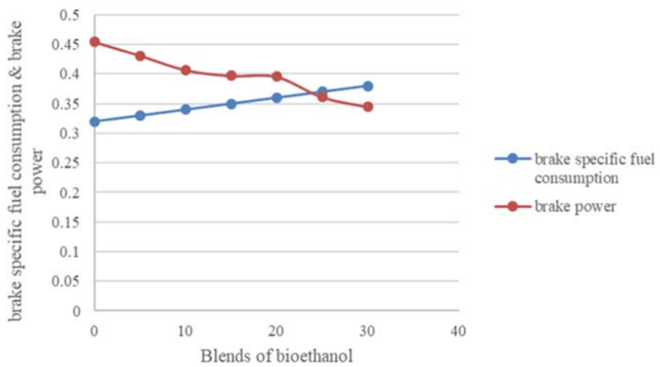

Figure 3. Effect of various bioethanol blends on brake specific fuel consumption and brake power.

Research on the compression ratio and brake power of various gasoline mixes has shown that, across the board, a 20% mixture performs as well as pure gasoline at all ratios. With a 20% mix or pure gasoline, the ideal braking power. Power development has been slower at lower compression ratio for the other mixes. Therefore, the ideal mixture to provide the same power as pure gasoline is 20% ethanol.

Brake specific fuel consumption decreases with increase in compression ratio [7]. Among all the tested blends E20 & E25 will shows the linear relationship between brake specific fuel consumption and compression ratio. The graph clearly depicts in figure 1 that further increase in bioethanol concentration will leads to adverse effect which is depicted by the curve E30 blend.

Brake power increases with increase in compression ratio [31]. The E20 blend curve satisfies this condition and remaining blends will deviate from the standard condition. Lower bioethanol concentration results in more fluctuation which is shown by E5, E10 & E15 curves, while higher bioethanol concentration will results in contradiction of standard condition. Hence there should be an optimal bioethanol concentration to achieve better power output, this is depicted in figure 2 & satisfied by E20 blend curve.

3.3. Effect of performance of various fuels on brake power and specific fuel consumption

The Effect of performance of various fuels on Brake power and SFC is shown in figure 1 The Brake power decreased 3%, 6% , 8%and 2% for E05,E10, E15, E20 ,E25 and E30 fuels respectively as compared to E0 fuel. High heat of evaporation provides fuel–air charge to cool and density to increase [32], thus higher power output is achieved as compare to gasoline only. However, Brake power starts to decrease shrply when ethanol percenttage is raised [7] to more than E20. With the use of E30fuel, it is observed that a 4% decline in power as compared to E0 fuel. The SFC increased as the ethanol percentage in blend increased. Increment of 10%, 19%, 37% 39%, 45% and 56% in the SFC were recorded with E05, E10, E15 ,E20, E25and E30 fuels respectively. This results are in confirmation with the findings of M BCelik [33]

The increase in bioethanol concentration increases the brake specific fuel consumption and decreases the brake power. The intersection point [34] of these two curves will give the optimized bioethanol blend concentration. Figure 3 will clearly describe that optimized bioethanol blend will fall between 20% to 25%.

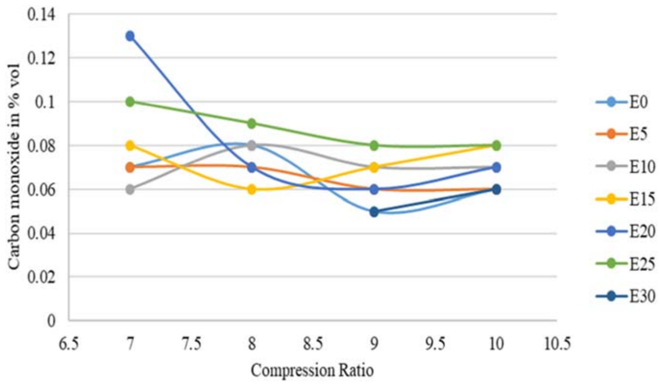

Figure 4. Carbon monoxide versus compression ratio.

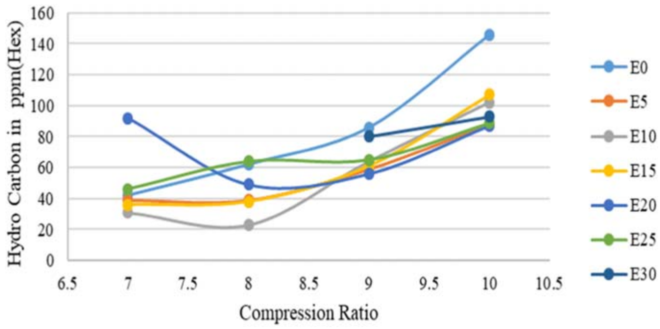

Figure 5. Hydro carbon versus compression ratio.

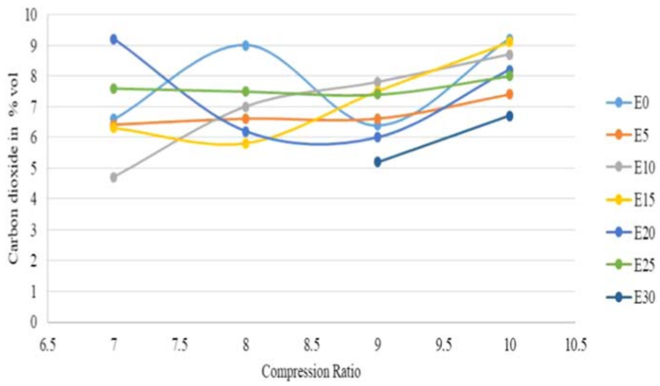

Figure 6. Carbon dioxide versus compression ratio.

Carbon monoxide is produced due to incomplete combustion. As the bioethanol concentration increases the combustion time increases and results in complete combustion which inturn reduces the carbon monoxide emission which is showed in figure 4 and clearly depicted by E20 curve.

Early combustion initiation results in elevated hydrocarbon emission. Figure 5 showed that hydrocarbon emission will be less at lower concentration of bioethanol, while it increases with lower intensity at higher concentration of bioethanol blend.

Carbon dioxide [35] is produced when the fuel doesn't burn completely, the carbon in the fuel converted in to carbon dioxide. Since the bioethanol contains less carbon content than gasoline and produces less carbon dioxide. E20 blend exhibit an inverted bell shaped curve, which clearly depicted in figure 6 that there should be an optimal bioethanol concentration to reduce the carbon dioxide emission.

Increase in bioethanol blending concentration the nitrogen oxide emission decreases [9] due to lower heating value shown in figure 7 compared with gasoline. All the curve except E0 will shows linear relationship

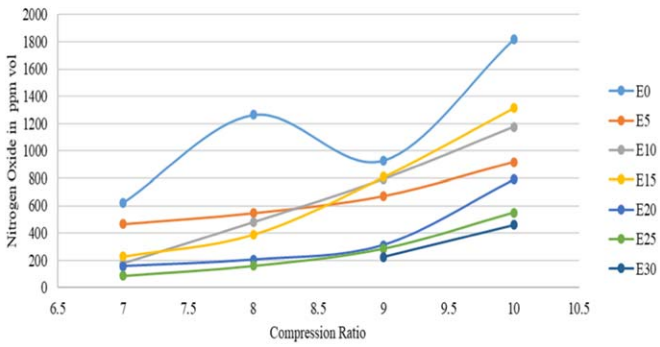

Figure 7. Nitrogen oxide versus compression ratio.

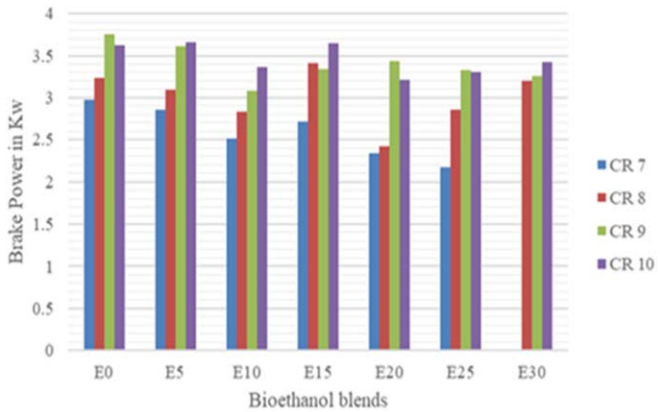

Figure 8. Comparision of brake power with compression ratio for various bioethanol blends.

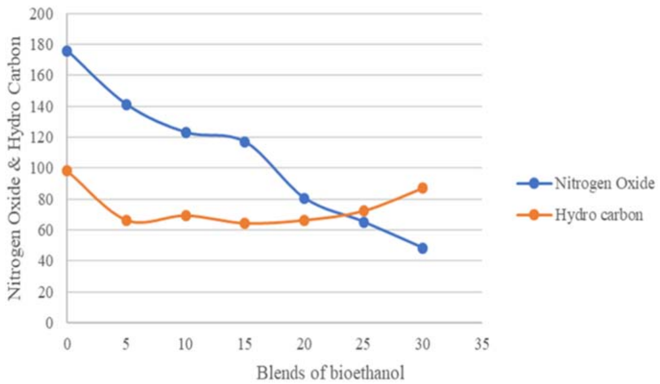

Figure 9. Effect of various bioethanol blends on nitrogen oxide and hydro carbon emission.

between nitrogen oxide and compression ratio. The addition of bioethanol concentration will results in cooling of the intake air—fuel mixture and lower the combustion temperature which in turn supress the formation of nitrogen oxide.

The effect of various fuel blends on brake power at different compression ratio [34] is presented in figure 8. The brake power was maximum at 9:1 compression ratio at rated speed of 1500 rpm for all the blends tested Engine was produced more torque as compared to gasoline only, for all the speed range. This may because of higher latent heat of evaporation of ethanol [36].

The effect of Various fuel blends Hydro Carbon and Nitrogen Oxide Emmission is presented in figure 9. It was noticed that the Hydro Carbon emission decreased with the ethanol percentage in the blend increased. It was also observed that the Hydro Carbon emission increased [37] when running with E20 and E25 fuels. As the ethanol percentage in the blend increased, Nitrogen Oxide value decreased. The intersection point of the graph in figure 9 clearly denotes that the optimized bioethanol concentration will be in the range of 20% to 25%. This results are in confirmation with the findings of M BCelik [33]

4. Concluding remarks

On a computerised variable compression ratio research gasoline engine synchronised with IC Engine software V 9.0, research experiments were conducted for bioethanol blend concentrations ranging from E0 to E30 at compression ratios up to 10. The E20 bioethanol blend's brake power curve and brake specific fuel consumption are comparable to those of gasoline, but other blends exhibit greater variation. Carbon monoxide, hydrocarbon, carbon dioxide, and nitrogen oxide emissions all decline as the concentration of bioethanol rises and the compression ratio increases. Brakepower is best achieved when ethanol is blended into gasoline up to 20%. Using E20 fuel at a 9:1 compression ratio resulted in a 29% increase in engine power over E0 fuel. Based on the blend's ethanol percentage, the reduced energy content of the bioethanol-petrol blended fuel raised the brake specific fuel consumption. This implies that for higher levels of bioethanol blends, the engine might experience knocking problems at lower compression ratios. This research can be extended to other bioethanol sources, and the current work will start the design of engine modifications for better performance at higher concentrations of bioethanol blends. According to the Indian government, gasoline should contain 20% ethanol by 2030. By mixing ethanol with gasoline, India can reduce vehicle emissions, aid local farmers and businesses, and reduce its dependency on imported fossil fuels.

Acknowledgments

Apex Innovations Pvt. Ltd, located in MIDC Kupwad, Sangli, Maharashtra, India, was the location where the research testing was carried out. A synchronization has been achieved between the Research petrol Engine and IC Enginesoft V 9.0.

Data availability statement

The data cannot be made publicly available upon publication because no suitable repository exists for hosting data in this field of study. The data that support the findings of this study are available upon reasonable request from the authors.

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