Performance analysis of pine oil with benzyl as additives in direct compression ignition engine

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ABSTRACT: Fossil fuels supply 84% of world’s energy. Almost of the world’s population are persuaded in using of fossil fuels as a primary fuel where mostly Petroleum and Diesel are used as a major requirement in automobiles. Diesel engine are mostly preferred for heavy transportation and agriculture sectors for carrying enormous loads because of high work efficiency and low cost-setup. The properties of Diesel helps us physically with its Density, low viscosity, low flash point (>52°C), increased evaporation time and compression ratio of 14:1 to 25:1. With increasing usage of natural resources which are non-renewable shortage occurs with increase in Demand and pricing fluctuation in the fuel market. With all the problems faced researchers are working in finding an alternate fuel with same properties of fossil fuels. Some basic properties are Brake thermal value, viscosity of the fuel, density, specific gravity of fuel, flash point, self-ignition temperature, vapour pressure, compression ratio and more. Introducing Benzyl alcohol blending with pine oil and Diesel acting as base fuel with mixture in quantities starting with Diesel, B40, B60, B80, B40+5%, B60+5%, B80+5%, B40+10%, B60+10%, B80+10% total of 10 different values and calculating the outputs of BTE and BSFC. With loads 1.14, 2.28, 3.42, 4.56 applied on the engine. This paper concludes the work of Benzyl alcohol as fuel blends with Diesel and Pine oil which helps in increase in performance of BTE and BSFC with direct injection of the blends and their corresponding properties are studied at different loads in a Single Intake Direct Compression Ignition Engine (C224).

Keywords: Pine oil, Diesel engine, Compression Ignition Engine, biofuel, Emission

1. INTRODUCTION

In recent times bio-fuels mostly vegetable oil have gotten noticed to be acting as an alternate fuels for diesel engine, mostly because they can be used without doing any engine modification. These fuels have the potential to solve the energy crisis while also reducing toxic emissions. Burning of fuels makes them non-renewable and also causes in emission harmful toxic gases like Volatile Organic Compounds (VOCs), Nitrogen oxide (NOx), Carbon monoxides(CO) and many more greenhouse gases which pollute the environment and living creatures around it. When compared to fossil fuels, food oil tends to release less amount of gases which can be controlled with proper additives. Diesel is treated as a crucial fuel entity and it is high preferred in automotive industry due to its high efficiency to work and its set-up is low when compared with petrol. Diesel is also good at working in transportation sector where vehicles should carry enormous loads and most importantly used in agriculture for doing high load works. Diesel has some specific properties like lower flash point, viscosity is measured low. It has high compression ratio which helps in higher thermal efficiency. Pine
oil’s properties are well synced for using in diesel engines, with remarkable advantages such as boiling point, lower viscosity and calorific value comparable to diesel. It has a lower cetane number, kinematic viscosity, and boiling point than diesel. Pine oil is being considered as a possible alternative to diesel because of its intrinsic O2 content, high calorific value, and good solubility. Pine oil consumption resulted in lower CO and HC emissions while increasing CO2 and NOx emissions. Most studies conclude that the use of alternate fuels in internal combustion engine are methanol, ethanol, butane because of their burning properties.

As a diesel alternative, alcohol-based fuels are largely efficient. Alcohols are used as fuel blending elements to enhance unspaced cetane quality. Cetane ignites rapidly when exposed to a little amount of heat, improving O2 content in diesel blends and improving knock resistance. bnOH alcohol is a long-chain which can be mostly observed in cosmetics, hair products, skin care products. It has a bad odor or pungent smell. It is a colour-less liquid, it is a useful solvent due to its rate of polarity and less vapor pressure. It is more soluble in nature which will be useful for mixing and because of its less poisonous it is a valuable solvent. bnOH alcohol is an aromatic compound. Short-chain alcohol like ethanol is used in IC engines which evaporates quickly. We’ll be using a long chain alcohol because of its properties like bio-degradable and can be obtained from natural fats and oil. Mixtures of B40, B60, B80 is prepared with 5% and 10% in concentrations of Benzyl alcohol. Benzyl alcohol is an aromatic compound with chemical formula C6H5CH2OH or bnOH. Benzyl alcohol is mostly used in hair products and cosmetics. The higher evaporation rate of aromatic alcohol, along with the presence of the OH group in bnOH alcohol, helps to burn quickly, resulting in a higher heat release rate. V. Mathan Raj [1] worked on the effects on 1-pentanol and bnOH alcohol with Diesel blends at B20 and B40 along with 5 to 10% addition injecting the mixture directly in a Kirloskar make four stroke CI engine at revolutions of 1500 rpm with power output of 5.2 kW. Both aliphatic and aromatic alcohols is chosen for hydroxyl group in its structure. After experiment is done BTE and BSFC is calculated and histogram graph is plotted with loads 1.3kW, 2.6kW, 3.9kW, 5.2kW respectively. Discharge gases namely HC, NOx, CO2 and CO emissions were analyzed using AVL Digas 444 model analyzer. B20 and B40 blends are observed that releasing less NOx and more smoke without the addition of 1-pentanol and benzyl alcohol. HC and CO emission are higher in B20 and B40 blends but seem to be decreased with alcohol addition. Addition of alcohol improves the bad execution done by normal blends (B20 & B40). Harmful emissions can be completely contained by mixing alcohol. Here 1-pentanol decrease NOx value more effectively than bnOHOH alcohol, other than that bnOH alcohol provides more performance than n-pentanol. Author also noticed the longer time required to ignite in B20 and B40 blends contrasted with diesel and being drawn-out by using 1-pentanol blend. R. Vallinayagam [2] works on fumigating pine oil in single cylinder diesel engine making it more effective with three different flow rates, 0.0291 g/s, 0.0873 g/s and 0.13968 g/s. Mechanical pump with three nozzle is used to inject fuel at specific bar pressure at 23o bTDC. Author here found that pine oil can restore diesel up to 36% and 60% at under full and low load situations respectively working with the conditions author has noticed that HC and Co emissions are decreased up to 47 % and 67% when compared with diesel. Smoke opacity gradually decreased with the increase of NOx emission. Due to better combustion in the chamber O2 discharge is observed to be decreased than that the diesel.

Hazrulzurina Suhaimi et al.[3] has conducted an study on 2-EH which is added into DF for producing a long chain alcohol diesel blend. The author has taken 5, 10 and 20% of 2-En into the DF and the mixtures were processed with equipment named ultrasonic emulsifier device at a speed of 20 Hz. Under various loads at a constant speed of 1800 rpm the results shows the calorific value as 45.87 mega joule/kilogram, density as 806.1 kilogram/meter3 and viscosity as 3.02 mPas. Also the author as seem to obtain raised pressure for HE10 is elevated by 0.69 percent and for HE20 is increased by 2.99% than the DF. This is due to raise cetane quantity of 2-EN. The HRR for HE5 has increased by 4.2%, 11.9% for HE10 and 15.6% for HE20. The author has also observed that the peak HRR increases as load is multiplied for all
each samples. Because the gradually increase in load influences for high rates of temperatures and cylinder pressures. It is also observed that the HE5 blend has higher BTE and the BSFC is lower when compared to other blends. And also the exhaust emissions decreased CO, HC, CO₂ and NO₂ by using HE5 blend. T.Balamurugan et al.[4] has the performance and emissions by blending specific alcohol blends like n-propanol and n-butanol. These blends were made separately at various propositions like 4% and 8% by the volume of diesel. And comparison of n-butanol and n-propanol blends were made on combustion, emission and performance characteristics. Performance characteristics has noticed that, at 80% of load, the BTE was increased by 10579.7,635.8,917 and 10.518% by the addition of 4 & 8% of n-butanol and 4 & 8% of n-propanol separately with the diesel respectively. And coming to the emission test it has been observed that the smoke opacity has been elevated by 12.891 & 5.078% for 4 and 8 % of n-propanol and 11.338% &14.063% for 4 & 8% of n-butanol.And the decrease in Nox emissions has been decreased by 6.098 & 19.665% for 4 and 8% of n-propanol and 11.58 & 14.329% for 4 &8% of n-butanol. From these results it has been considered that addition of n-butanol resulted better performance when compared to n-propanol. R. Vallinayagam et al.[5] has used double bio fuel, pine oil KME blend in an diesel engine and studies the properties of these both bio fuels. The author has observed unique properties for both the bio fuels in the diesel engine. The author has tested these bio-fuels for the combustion, emissions and performance characteristics in a single cylinder diesel engine. From the results it has been noticed that the BTE has been increased by 8% for B25P75 than the diesel at full load circumstances, and also the minor HC, CO and smoke emissions were observed when compared to diesel by 14.9% of HC, 43.2% of Co and 33.4% of smoke. It has also observed that the engine tends to prone at higher loads and so the adaptability of B50P50 has been considered. For B50P50, the BSFC and BTE were agreeable with the diesel, and it has been noted 8.1% of HC, 18.9% of Co and 12.5% of smoke were lower when compared to diesel emissions. The diesel is lot more influenced over B25P75. From this results it can be stated that B50P50 could be noted as an best blend among all the blends and all the studies the author has concluded that B50P50 has attained supreme properties, similar performance with diesel and decreased engine emissions.

Yuvarajan Devarajan et al.[6] has studied the performance characteristics of bio diesel produced from neem which is known as BD100. The concentrations of this bio diesel was maintained as 80 and 90% where the volume of decanol were 20 % and 10 %. Diesel is burned in engine to get steady set-up or steady state. From the tests it has been noted that no partition of phases were found by blending the BD with the decanol in BD. At higher heating values of neem bio diesel blend, it ended with higher HRR and ICP than the neat bio diesel. High oxygen content has also improved premixed combustion of decanol a fatty alcohol in neem bio diesel blends, leading to increased BTE and lower fuel consumption, according to the source CO, HC, and smoke emissions are lowered by using a diesel engine that runs on neem bio diesel blends. And this blend provides a leaner mixture by make complete combustion than bio diesel. The decanol in the Azadirachta indica(neem) bio diesel blend, according to the author has a quenching effect and lowers the fuel burning temperature. Inside the engine, thermal efficiencies have improved by 0.5 percent, and CO,HC, and smoke have been lowered by 4.8,2.4, and 3.2 percent, respectively, compared to diesel. According to the author, a blend of 80% neem green diesel and 20% dacanol will boost combustion, emissions, and performance.

Anandavelu et al [7] work helped us to study about the Kirloskar TV-1 engine. Work studied from this paper is knowing about main properties achieved by using EGR in CI engine and conclusions taken from it. Without EGR it is concluded the difference in BTE in all EOF mixtures. We also concluded that how much pressure that TV-1 can withstand at working conditions. Mixtures of E40 is observed to releasing less amount of smoke than DI of diesel. High difference in NOX discharge is calculated that is percentage of 50-60 with EGR in action. E50 + EGR of 15% achieves the higher position in BTE graph and BSEC is known to be more efficient than BSFC in terms of finding elevated values for different fuels.
It is also concluded that as load on the engine increases smoke opacity from the engine also tends to increase the O2 level is compromised. From the following experiment it is known the significance in the work of EGR in bio-fuels in CI engines. Wang Jianxin at el [8] works on pentanol blends as addition to the bio-diesel and its working parameters. This paper elaborated the use of alcohol as diesel mixtures helps us to use bnOH alcohol as additives. It showed us there are many more mixtures that can be used with specific properties that can easily blend with green fuel without reacting differently. It showed the different emission value at different loads from diesel can be altered with the help of alcohol mixes at correct quantity. Author explains the involvement of pentanol to lower the harmful gases released from CI engine when diesel burn and working on alternate fuel to lessen the green house gases. Formation of CO gases are caused by un-burned fuel in the chamber leads to increased discharge of CO gases. Author explains that addition of chemicals at well known composition and properties helps in lowering the chances of release in harmful gases which is occurred by DI of diesel or any other fuels.

2. METHODOLOGY

The paper focus on alternate fuels without compromising with power that is about to be offered by the engine with emissions in control as well. The alternate fuels of B40, B60, B80 are prepared with pine oil mixture in the ratio of 40% pine oil and 60% diesel in 4:6 ratio. In B60 the ratio is 6:4 where pine oil is 60% and diesel is 40%. In B80 the pine oil dominating the ratio with 8 parts with pine oil carrying 80% of the mixture and diesel 20%. The mixture is mixed in 1 litre burette under atmospheric temperature. The mixture is then experimented in Cal224 engine which is a single intake direct compression ignition engine. The placement of the hydroxyl group can be seen in the molecular structures of 1-pentanol and bnOH alcohol. 1-Pentanol is an aliphatic alcohol with a straight chain, whereas bnOH alcohol has an OH group bound to the aromatic C6H6 ring and is thus it is an aromatic compound. The further insight of benzyl blend was experimented in the mixture of B40, B60, B80 removing 5% of the mixture and replacing it with benzyl forming the following blends B40+5%, B60+5%, B80+5%. The 1st batch of 5% benzyl blend is experimented which showed an impressive increase in performance. Thus the 10% benzyl experimental idea led out to the mixture blends from replacing 10% into benzyl forming B40+10, B60+10%, B80+10%. All these blends and mixtures ran were tested in CAL224 diesel engine and the results were formulated. Because of the expense of the gasoline blends, the blend proportion of all alcohols was reduced to 5 and 10 percent. The blends were made using the splash blending process, and all of the fuel blends were found to be completely miscible and reliable during processing. Also after 48 hours, there is no phase separation in the prepared samples. The blends were fueled into the engine and the engine were experimented to perform at various loads such as 0, 25, 50, 100 that is 1.14, 2.28,3.42, 4.56 (kW) all through constant speed of 1500 rpm. The experiment test results were discussed and tabulated. The performance were analyzed using engine soft software. The exhaust pipe were interconnected to the exhaust gas analyzer generating the report of the given mixture blends tests. The results were tabulated and analyzed the best performing mixture.

2.1 Experimental Setup

All the experiments were performed in a Kirloskar TV1 four stroke diesel engine manufactured by Kirloskar, at rated energy output of 5.2 kilowatt with 1500 rpm. The engine specification is tabulated in Table 1. The engine is equipped with an eddy-current dynamometer with an electronic exciter for converting mechanical to electrical energy and being measured. Fuel intake was calculated volumetrically with burette container and stop watch. The temperature of the discharge gases is been measured with a K-type thermocouple fixed to the digital display. The gas pollutants, such as HydroCarbons, Oxides of N, CO₂, and
oxides of C, were investigated using an AVL Digas 444 model analyzer, which works on the principle of NDIR. The light extinction mechanism was used to measure smoke density with the help of AVL 437C model Opacimeter. Before beginning the trial, the gas analyzers were adjusted to zero.

Table 1: Engine Specification

| Engine Type                              | Single Cylinder, Water Cooled, Direct Injection, Constant Speed Diesel Engine |
|------------------------------------------|--------------------------------------------------------------------------------|
| Cylinder Bore                           | 87.05 Mm                                                                      |
| Stroke Length                           | 110 Mm                                                                        |
| Compression Ratio                       | 17.5:1                                                                        |
| Rated Power                             | 1500 at 5.2 kW                                                               |
| Injection Pressure                      | 200 Bar                                                                       |
| Injection timing                        | 23° bTDC                                                                     |

The engine equipped with an eddy-current dynamometer with an electronic exciter for measuring and varying the load. Fuel intake was calculated volumetrically using a burette container and a stop watch. The temperature of the emission gas was measured using a K-type thermocouple connected to the digital display unit. The gas pollutants, such as HC, NOx, CO₂, and CO, were investigated using an AVL Digas 444 model analyzer, which works on the principle of NDIR. The light extinction mechanism was used to measure smoke opacity using the AVL 437C model Opacimeter. At the beginning the trial, the gas analyzers were calibrated. The pressure within the cylinder is calculated using a Kistler pressure transducer attached to a computer-based data acquisition system. An encoder in the flywheel is used to calculate the crank angle. Using the ‘Engine Soft’ programme, various burning parameters such as in-cylinder pressure, heat release rate, burning fuel duration, and combustion duration were obtained. Every value were taken for 100 cycles to minimize cycle-to-cycle variability, and the average was used for comparison. At a constant engine revolution of 1500 rpm, all of the measurements in this study were taken from loads gradually increasing, resulting in BP of 1.14kW, 2.28kW, 3.42kW, and 4.56kW. Throughout the experiment, the fuel injection timing was kept stable at 23° bTDC. The fuel injection timing was held at 23° bTDC throughout the trial, with a constant injection pressure of 200 bar. Throughout the trial, the fuel inlet fuel
timing was held at 23° bTDC, with a steady injection pressure of 200 bar. All of the tests were performed in a steady-state condition with no modifications to the test engine. After all calculations were done multiple times for various mixtures, the average value is taken to calculate the obtained parameters. To warm up the set-up, it was first run on diesel for 15 minutes. The emission parameters such as HC and NOx are measured in parts per million, while CO was measured in percent volume and translated to grams per kilowatt hour depending on the number of moles. The square root method is used to calculate the variance of both output and pollution parameters.

3. RESULTS AND DISCUSSION

From performing the test in C224 Single Intake Direct Compression Ignition Engine the values which are obtained are used to drawn Histograms between BTE vs BP and BSFC vs BP. From the values obtained conclusion can be done that mixture such as B40+5%, B60+5%, B80+10% has shown performing better and much similar when compared with Diesel. For further evaluation Emission characteristics are taken AVL Digas 444 model analyzer. Emission value obtained are used for drawing histogram being taken differences from diesel ignition values. The graph shown in figure 2 is drawn between Brake power and BTE showing the compared values of performing differences between Direct diesel injections and blends did for experiment. BTE is the BP acquired from the set-up to the fuel energy contributed for the engine. It is used to determine how efficiently an engine transfers heat from fuel into mechanical energy. The force exerted on a friction brake or absorption dynamo-meter applied to the flywheel or shaft to measure the brake power of an engine or other motor.

The listed graphs explains the comparison between the performance of the various experimental blends of B40, B60, B80 pine oil blend with diesel as a base oil in the ratio of 4:6, 6:4, 8:2 between Brake power and Brake thermal efficiency. The ratio of the blends change of BTE according to the addition of loads on the set-up. The experiments led out to a research insight into adding 5% of benzyl as a catalyst to the mixture to analyze the performance. The analysis on the experiments led out to the results of B60+5% benzyl shows the overall performance of 31% brake thermal efficiency with 33% at 4.56 brake power compared to Diesel, with benzyl in place its inflammable nature burns all the un-burned fuel in the mixture producing better thermal efficiency. Adding to that 10% of the mixture is also experimented with and analyzed. Next down the lane, B40+5% benzyl and B60+10% benzyl shows overall 95% BTE benzyl boosting the better thermal efficiency even at higher loads they have solid bond mechanisms which are particularly resistant to combustion owing to the presence of several double-bonded carbon atoms and a cyclic composition. With the mixture of pine oil dominating the B80 mixture its shows to be less efficient among the list because the mixture of diesel is 2/10 pine oil has less density and resistance to ignition reducing its inflammable nature wherein B80+ 10% showed better performance among the B80 batch because of the percentage of high octane no. of aromatics in the mixture. The performance of B40 and B60 has been improved with the benzyl. Hence it is concluded that the mixture of pine oil with diesel in a 6:4 ratio with 5% of benzyl blend shows 97% efficient compared to diesel's performance.

The histogram in figure 3 is drawn from the experiment done in TV1 engine and evaluated values are used to determine the difference between BP and BSFC. It is compared alongside with diesel as base fuel and specific alcohol blends. BSFC is the estimation of productivity of fuel by the engine that combusts the fuel air blend and delivers the rotational movement of the driving rod or also known as crank shaft. This is utilized to think about the motor's exhibition. The BSFC is the proportion of the engine's useful capacity to its pace of fuel utilization. The force released on a friction brake or absorption dynamo-meter applied on a flywheel or shaft to quantify the BP of an engine. The above data is graphed between BP and BSFC data and it
has been analyzed that the B60+5% consume fuel of just 3% more than diesel to get the work done, getting 97% of work done compared to direct diesel injection into the engine producing more power even at higher loads engraving most thermally efficient among the experimental mixtures because the mixture is denser and has the better knock resistance to withstand the pressure producing more thermal efficiency with high energy content hydrogen double bonds of benzyl.

![BTE vs BP](image1)

**Figure 2. Brake Thermal efficiency vs Brake Power**

![BSFC vs BP](image2)

**Figure 3. Brake Specific Fuel Consumption Vs Brake Power**

Similar with B40 +5% and B60+10% of benzyl blend produces power with better fuel economy entitling the presence of mixed properties of dense benzyl diesel mixture and low flash point of pine oil sustaining from getting vaporized. B60 and B40+10% has similar outputs almost showing the same performance with break thermal efficiency but with help of Benzyl,performance of B60 is improvised in B60+5%. Whereas B80 and B80+5% performance has shown to consumes more fuel because of less dense pine oil dominating the mixture with 8:2 ratio its thermal efficiency is low enough to get the work done resulting in increase in fuel consumption.

### 3.1 Emission Analysis

Diesel engine emissions include pollutants that does have adverse effect in health and environmental. Many of these pollutants is sourced from various non ideal processes experienced during combustion, such as incomplete combustion, reactions between components under high temperature and high pressure, combustion of lubricating oil in the
engine, oil additives and combustion of non-hydrocarbon components. Common pollutants do include hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx) or particulate matter (PM).

The histogram graph in figure 4 is plotted between BP verses NOx discharges from the analyzer. When fuel is burned at high temperatures, NOx is produced as a result of a chemical reaction in the air. The strong triple bond of nitrogen structure molecules breaks in the presence of O2 at high combustion temperatures, resulting in NOx. Fig 2.1 shows the emission rate of NOx at different loads. NOx condition is lower than diesel at load 3.42kW and 4.56kW respectively with blends B40 and B40+5%. Even though oxygen content is higher than others NOx emissions stays lower due to its poor combustion in the chamber. Reducing the emission of NOx can be done by EGR. A percentage of the exhaust gas is cooled and reintroduced into the combustion chamber. Since any of the oxygen in the exhaust gas has been absorbed by past combustion, there is no fuel to fire. The heat capacity of exhaust gas is higher than that of air, so it takes longer to heat up.

The histogram graph in figure 5 is mapped between BP verses Emissions of smoke from Digas analyzer. As the load increases on engine Smoke emission also increases because of the incomplete combustion in the chamber. At 3.42kW smoke emission reduced from 50.3% to 25.6% because of diesel quantity in B80 is in 8:2 ratio 80% of pine oil and 20% diesel, and with it B60+5% and B80+10% produces 27.5 and 25.8 percentages simultaneously. Smoke emission is observed to be decreasing simultaneously compared with diesel due to its mixture ratio. Smoke emission is reduced because of better combustion, increased oxygen supply, and lower carbon content, alcohol blending with the respective fuel makes less smoke. Since benzyl alcohol has a complex carbon structure and oxygen content, it can theoretically increase smoke emissions, whereas when combustion increases temperature also increases reducing smoke emission.

![Figure 4. Emission of NOx under different loads and mixtures.](image-url)
Figure 5. Emission of smoke under different loads and mixtures.

Figure 6. Emission of CO₂ under different loads and mixtures.

The histogram graph in figure 6 is mapped between BP verses Emissions of CO₂ from Digas analyzer. Diesel has high fuel efficiency which helps produce lower carbon dioxide emission. As we all know that emission of CO₂ increases with increase in load. The above histogram graph shows the increase in CO₂ emission with increase in load respective to the mixture used. At 75% and 100% load CO₂ emission are seen to decrease because of the mixture quantities present in it. Blends of B40 always shows the lowest emission rate of all in each load with its mixture ratio 60% of Diesel and 40% of pine oil. With pine oil in presence which has flash point of 65°C and boiling point is 195°C which remains un-burned in the chamber which reduces the emission of Carbon di-oxide.

The histogram in figure 7 validates the emission value plotted between BP and emission of hydrocarbon. In each load B80+5% can be seen at high rate of emission caused by the high pine oil content and addition of alcohol makes the fuel burn more, with increase in more load temperature to burn fuel increases and it causes more
emission in hydrocarbons. At load 1.14 highest and lowest emission values are marked with 79% and 16% respectively. We can observe increase of HC emission slightly with small amount with the increase in load.

![HC Emission Graph](image)

**Figure 7.** Emission of HC under different loads and mixtures

![Emission of CO Graph](image)

**Figure 8.** Emission of CO (Carbon monoxide) under different loads and mixtures

The histogram graph in figure 8 is drawn between BP verses Emissions of CO from Digas analyzer Carbon monoxide (CO) is emitted when combustion reactions do not complete properly, either due to a lack of oxygen or due to insufficient mixing. Carbon monoxide is a gas that is both colourless and odourless, with the excess-air factor (λ) being less than 1. CO is flammable gas with a density significantly lower than that of air. One carbon atom and one oxygen atom make up carbon monoxide. Addition of alcohol caused Emission spike up at maximum loads.
4. CONCLUSION

This study shows the effect of pine oil and benzyl alcohol with Diesel blends on performance and emission when burned in Kirloskar TV1 engine. Blends of B40, B60, B80 and 5% and 10% of benzyl alcohol for each blend taken total of 9 blends with diesel as base is analyzed and compared with diesel. After burning the fuel in the engine using AVL Digas 444 model analyzer emission values are taken and histogram graphs are drawn and analyzed. Based on the acquired values following conclusions are taken:

- It is evidently shown through analysis that the B60 with 5% and 10% has been producing equal to more thermal efficiency in higher loads compared to diesel with less fuel consumption. It also produces competitive results compared to diesel but it seem to consume more fuels compared to others in list while producing similar or more thermal efficiency than B60+5%.
- Fuel consumption of B60+5% can be observed consuming less fuel than of other blends and when compared with diesel it almost consume bit lower than base fuel.
- Blend of B40 emits less NOx but higher smoke opacity when alcohol is added to the blends to leading increased NOx emission with reduced Smoke opacity.
- Blends of B80 has been noticed with higher emissions in HC and CO but been reduces with addition of alcohols, CO and HC emissions were higher at minimum loads cause due to high latent heat of vaporization.

Nomenclature:

- \textbf{BTE}: Brake Thermal Efficiency
- \textbf{BSER}: Brake specific energy consumption
- \textbf{cSt}: Centistrokes
- \textbf{NDIR}: Non-dispersive Infrared
- \textbf{BnoH}: Benzyl Alcohol
- \textbf{CO}: Carbon Monoxide
- \textbf{O}_2: Oxygen
- \textbf{PM}: Particular Matter
- \textbf{BSFC}: Brake specific fuel consumption
- \textbf{bTDC}: Before Top Dead Center
- \textbf{DI}: Direct Ignition
- \textbf{EGR}: Exhaust gas re-circulation
- \textbf{NOx}: Oxides of Nitrogen
- \textbf{VOCs}: Volatile Organic Compounds
- \textbf{TDC}: Top Dead Centre
- \textbf{CO}_2: Carbon di Oxide
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