Performance and Emission Analysis of Pine Oil in Single Cylinder Diesel Engine

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***Abstract* -** Environment pollution, increasing fuel prices and its demand have promoted an interest in development of alternative fuel for petroleum products. Biofuel is preferred as an alternative fuel for IC engines due to its abundant availability and renewable nature. It is renewable, biodegradable, oxygenated, sulfur free and reduces their adverse effects on climate change.

In the present study, we have introduced a new type of biofuel, pine oil for the purpose of fuelling in diesel engine. Significantly, pine oil is unique in that the feedstock originates from forest Notably, the viscosity, boiling point and flash point of pine oil were observed to be lower than diesel, qualifying as a suitable alternate fuel under less viscous biofuel category. When compared to less viscous alcohols as well as high viscous biodiesel, pine oil has comparable calorific value with diesel, which forms the profound advantage and distinction of the proposed fuel herein. Having ensured that pine oil is conducive for its use in a diesel engine, it was experimentally investigated in a diesel engine in different modes viz. blend, dual fuel modes. In the present study the performance and emission characteristics of a single-cylinder, constant speed, DI diesel engine using pine biofuel blends (P10, P20, and P30) as partially substituted fuel were studied. The results are compared with standard diesel fuel. The test results indicate that there is a slight decrease in brake thermal efficiency and an increase in brake specific fuel consumption for all pine blended fuels when compared to diesel fuel. The tested blends resulted in lower emissions of CO, HC, NO_X and CO_2. The experimental results prove that the use of pine oil blends in the compression ignition engine is a viable alternative to diesel.

Index terms :

I. INTRODUCTION

Escalating petroleum prices, increasing risk to the natue from emissions of vehicle exhaust, stringent environmental laws and quick depleting supply of oil based commodities have created an extraordinary worldwide enthusiasm in developing alternative renewable fills for IC engines.

Environmental awareness was first brought to open consideration the 1960's when smog became an issue in large cities like Los Angeles, Tokyo and Mexico City. Since then, environmental awareness has increased with expanding information of the natural harm caused by, among other human exercises, use of non-inexhaustible sources for industry and transportation. Consuming petroleum derivatives emit $C0_2$, a gas which is chief heat trapping gas causing the well-known phenomenon of greenhouse effect. With greenhouse effect on earth, concentration of CO_2 in air is guaranteed to frame a sort of cover over earth's surface stopping heat emanated from the earth from getting away to the space. It has been shown that this phenomenon has been responsible for observed and predicted increment in the normal temperature on earth's surface. The outcome of increase of temperature of earth's surface is the threat for sea levels to rises, fierce storms, winds and heat waves. Over the years, agencies have been settle up all over the globe to formulate rules and procedures to curb the increment of CO_2 and other environmentally damaging gases like chlorofluorocarbons (CFCs), SO_2 and NOx. Reduction of CO_2 emission has been targeted as main step in checking greenhouse effect and a standout among the most effective ways is by switching to non-fossil fuels, demanding higher-mileage cars and energy-efficient industries.

A champion among the most important advances taken by the world community in this direction was the staging of the `Earth Summit' or officially, United Nations Conference on Environment and Development (UNCED) in June 1992. The summit drew heads of states and delegates from everywhere throughout the world, making it world's largest and also, the most imperative gathering on environment ever held. In it delegates counselled not withstanding different things, the essential terms for a lawfully restricting tradition intended to decrease the global warming.

The inescapable predetermination of the worldwide environment is a champion among the most fundamental issue today. Consideration has been called to the issue of practical advancement which accords environmental protection. It is awareness and worry for natural insurance that has provided the impulse to the greater part of ongoing research in use of non- fossil or other so called clean fuel for IC engines. Bio fuel is an oxygenated fuel which builds combustion and reduces exhaust emission. It can be formed by crops having high starch or sugar content. A segment of these products incorporate sugarcane, sorghum, corn, grain, cassava, linseed plants, sugar beets so on. Other than being the biomass based sustainable fuel, biofuel has cleaner consuming and higher octane rating than the different vegetable oils.

Many specialists trust that continuously 2070, the universe will be depleted of petroleum derivatives. Thus we have an earnest need to find alternate to them. Fundamentally the significant piece of vitality expended overall originates from non-sustainable power sources (petroleum, coal, natural gas) which are non-inexhaustible and furthermore the genuine reason for air contamination. Meanwhile elective fills are sustainable and furthermore addresses numerous issues like unnatural weather change and air contamination.

1.1 Indian Scenario: Energy Resources

Today, the energy is essential contribution for every financial action and has turned out to be fundamental for development in the personal satisfaction. Infact, the entire framework rests upon vitality. The energy usage of a country now-a-days is generally considered as record of its advancement. Around 24 percent of vitality expended universally, is utilized for transportation, 40 percent for industries, 30 percent for residential and business purposes and the remaining 6 percent for different utilizations including farming.

There is broad uniqueness in energy utilization in advanced and industrialized nations and growing nations. About 2 billion individuals, 33 percent of worldwide population living in developing nations, need access to satisfactory energy supplies. Three billion individuals rely on fuel wood, coal, charcoal, compost and lamp fuel et cetera to cook and heating. Then again, industrialized countries, with just 25 percent of global population, represent 70 percent of commercial energy utilization. India, with 16 percent of total populace, accounts only 3 percent of aggregate vitality utilisation. For a 100 units devoured by an American resident for transportation, a Japanese expends 30 units and an Indian expends only 2 units. The case is basically similar with other formative exercises.

Indian economy is farming based economy. Dominant part of its masses lives in village and uses wood, agricultural squanders, animals manure etc. as vitality source. In urban regions, in ventures, transportation, media transmission, domestic establishment etc., the energy expended is gotten from coal, oil, natural gas, hydroelectricity or atomic power. The enterprises guarantee an expansive offer (about 38.5 percent) of aggregate energy took after by transportation (about 31.2 percent), domestic establishment (about 13.7 percent) and the remaining in farming. Offer of various vitality sources in the commercial use of vitality in India generally arises from coal (about 56 percent) and petroleum (around 32 percent). Alternate sources are hydroelectric, nuclear power, natural gas etc.

Monetary development, increasing thriving and urbanization, ascend in per capita utilization, and spread of energy access are the key factors that would be in charge of significantly increasing the total demand for electricity. In this manner there is rising energy supply-demand unevenness. As indicated by Central Electricity Authority (CEA) report, the anticipated energy and peaking shortage in the nation was evaluated to be 10.3 percent and 12.9 percent, separately, in 2011 and 2012.

The cutting edge human progress is much subject to vitality accessibility however the vitality resources, chiefly oil, coal, petroleum gas and hydroelectric power are winding up rare and costlier. Prices of oil, the most generally perceived source of vitality, are going very high. To adapt to regularly expanding request, endeavours are being made to grow new methodologies in conventional and non-traditional vitality sources and new measures of vitality preservation.

1.1.1 Various Energy Sources

Energy may be characterised as the capacity to do the work. The diverse sorts of vitality, are as heat, light, motion, and sound. Sustainable forms of energy are wind, solar, wood, biomass. The uses of non-renewable source of vitality for example petroleum subordinates and coal may cause dangerous state of air contamination, water contamination and land contamination. The vitality can be isolated into two categories i.e. Kinetic vitality and Potential vitality. However there are numerous types of vitality, like thermal, electrical, motion, radiant, and sound energies that are Kinetic form of energy; while gravitational, stored mechanical, nuclear, and chemical energies are potential forms of energy. There are many different procedures to convert, store, and amplify the vitality that is present around us for their valuable use. Effects of energies are experienced only but it cannot be seen, so it usually a difficult matter to understand. For example, light and electric energies transfer by wave, but they are distinctive processes. Energy sources can be arranged into three gatherings fossil, fissile, and renewable. The term non-renewable vitality source alludes to that fuel which is shaped due to consequences results of long duration chemical reactions under high pressure in earth. The improvement of oil subsidiaries takes numerous years and isn't renewable. The fossil vitality sources are coal, oil gaseous petrol, tar sands, oil shale. The atomic vitality source can be delivered from fissile material like plutonium-239, uranium-235, and uranium-233. These particles are capable to keep up long chain reaction.

In this competitive world there is standard and quicker utilization of raw petroleum. The resources of raw petroleum are constrained subsequently there is demand to look for changed decisions for future to search a other of diesel/petrol which is most ideal, renewable and effortlessly open in nature. As the crude fuel resource is non-renewable and limited, so the fuel cost is expanding persistently because of increase in demand and reducing supply. The different nations across the universe are working to search an alternative for Diesel engine. Thailand is doing research on palm oil, U.S.A. is on soybean oil, Philippines is on coconut oil, Malaysia and Indonesia are on palm oil and Europeans countries have worked on sunflower oil et cetera. Diesel motor is more proficient than Gasoline engine. Therefore for the heavy-duty automobile, power generator and in irrigation sectors, diesel engines are broadly utilized. Henceforth, the usage of diesel is considerably higher than oil fuel. During combustion of petroleum subordinates there is consistently emanation of Green-House Gases (GHG) for example CO_2 which is causing an earth-wide temperature boost and environmental change.

1.1.2. Crude Oil Position in Present Energy Situation

Petroleum word is the combination of two Latin words one is Petra, which means "rock", and other is oleum, it means "oil". Petroleum is utilize to portray a long scope of hydrocarbons which are available in nature as solids, liquids and gases states. The physical properties of petroleum vary. The colour vary from pale yellow to red and brown to black. Two most basic types of the petroleum products are raw petroleum and natural gas. Raw petroleum is a compound of hydrocarbon that contain 45% to 96%

hydrocarbon by weight. The refining strategy of raw petroleum comprises the segment of oil into different hydrocarbon parts by distillation. The main contents of unrefined petroleum are given in Table 1. The boiling point of a hydrocarbon mixture is influenced by different variables.

Table 1: Crude Oil and its Contents

S.No	Contents	Boiling Temperature	Number of carbon atoms present
1	Diesel fuel	475 K to 625 K	C10 to C15
2	Gasoline	315 K to 475 K	C5 to C12
3	Kerosene	425 K to 535 K	C12 to C13
4	Petroleum	295 K to 335 K	C5 to C6
5	Natural gas	< 295 K	C1 to C4
6	Fuel oils	> 535 K	C14 and higher

The fundamental constituent of Natural gas (NG) is 80% methane (CH_4). Though the resources of NG are comparatively large as compared to conventional crude oil, but use of NG is considerably smaller than that the crude oil.

Coal is another important energy source. Coal is formed by a long process which may take number of hundred years. In the complete processes of formation of coal there are different stages, in which first stage includes process of plant, animal and different biomass compression process. Then after following various decades this biomass is changed over into brown coal or lignite. Lignite is already free from the original moisture, oxygen, and nitrogen. Then this brown coal is further converted into bituminous coal in number of years. This bituminous coal is available in huge amount and is the purest form of coal.

1.2 Alternative Fuels for Energy

Some alternate resources of energy are biodiesel, bio alcohols, synthetically put away power i.e. batteries, vegetable oil, hydrogen and different sources of biomass. Bio alcohols incorporate methanol, ethanol, propanol, and butanol. Ethanol and Methanol are the most regularly utilized bio energizes far and wide. Bio butanol can be used particularly in a fuel motor and is guaranteed as quick substitution for gas by the scientists. Liquor fills are delivered by maturation of sugars gotten from wheat, corn, sugarcane, potato and et cetera. The most well-known blends utilized as piece of engines are E85 (85% ethanol and 15% gas) and E10 (10% ethanol and 90% gas).

Expansion of 15% fuel is to kill issues like tank combustibility, crisp beginning, et cetera while E10 decreases the gas use by 10%. The benefit of utilizing alcohols are that alcohols can be acquired from numerous common sources and can in like manner be produced. Regardless it encounters drawback, having low vitality content, poor chilly climate beginning and start attributes.

Some alternative fuels for energy are biodiesel, vegetable oils, biomass sources, hydropower, thermal power, geothermal energy, wood pyrolysis, wind energy, solar energy, bio hydrogen and nuclear energy etc.

II. LITERATURE REVIEW

2.1 Introduction

The motivation to review the operational practicality of less thick fuels in diesel engine exuded after witnessing the progress in their production and utilization in a diesel engine in recent past. Despite the distinct fuel properties, the incursion of these less thick fuels into alternate fuel sector, as pertinent substitute for commercial petroleum diesel, has been on ascent because of their renewability, availability and biodegradability. As a rule, fuels which lower viscosity than diesel can be treated as less viscous fuels. Further, these fuels could likewise be viewed as light biofuels and are unmistakably recognized from biodiesel, orchestrated from vegetable oils, by temperance of their qualities. Unmistakably, these fuels have their inception from the parts of plants and different biomass and not from the seeds.

Further, fuels with lower viscosity ought to possess better evaporation, atomization and shower attributes than standard diesel. Most often than not, such less thick fuels have tendency to have bring down cetane number as they doesn't possesses any free unsaturated fats and their carbon chain lengths are moderately shorter. Normally, less gooey fuels identified thus far include ethanol, methanol, butanol, eucalyptus oil, dimethyl ether, diethyl ether and carbonate based fuels. Notably, ether based fuels and carbonates are being managed as added substance with either diesel or bio diesel to enhance fuel properties.

However, amongst these fuels, alcohols gains massive fame in the view of idea that the raw. From the summary of past review works, it is noticeable that only review on alcohol-diesel mixes has been contemplated and no review work on other operational modes of alcohol fuels such as fumigation, dual injection.

Similarly, review on operational plausibility of other classification of less gooey fuel, eucalyptus oil, in any of modes has not been managed until now.

In this setting, much to benefit of thriving researchers, we have started a survey deal with adjustment of less gooey fuels, alcohols and eucalyptus oil in diesel engine. Notably, though both fuels have lower viscosity, their composition and other properties are distinct.

Therefore, to being with, broad exploration of physical and thermal properties of these powers is made and effects of composition of fuel on their properties have been investigated. Further, blocking the discourse on motor characteristics of alcohol — diesel mixes, given lot of audit deal with them had been surfaced as of now, this survey has reported the other task plausibility of it in double fuel and single fuel modes. However, for other less gooey fuel, eucalyptus oil, its operational attainability in diesel engine in all possible modes has been imparted.

M. Habibullah et al.,[1] studied the coconut, palm and their joined mix with diesel. They use different blends (PB30 and CB30) and (PB15 and CB15) and evaluated performance and emission characteristics. They noticed that biodiesel mixes have low break torque and high BSFC. The emission except NOx were reduced compared to diesel. By experimentally it is analysis that combined blends of palm and coconut oil have the better performance and less emission over the individual palm and coconut oil.

I. M. Rizwanul Fattah et al.,[2] studied the effects of antioxidant on the performance and emission attributes of diesel engine with palm bio diesel mixes (B20). The production process of palm biodiesel was transesterification with KOH as catalyst. Engine used for experiment was four cylinder diesel engine and test led at steady load and changing pace. The antioxidant used BHA and BHT. It was watched that B20 and antioxidant-treated B20 delivered 0.68 – 1.02% lower BP and 4.03 -4.71% higher BSFC compared to diesel but both antioxidant reduced the NOx by average of 9.8 – 12.6% compare to B20. The emission level was lower when compare to diesel so snit oxidant can use in diesel engine with no alteration.

Pramod S. Metha et al.,[3] studied combustion, performance and emission of neat Karanji biodiesel and its mixes with methanol in multicylinder diesel engine. Consequences of test examination demonstrate that ignition delay for biodiesel-methanol mix was somewhat higher than the perfect biodiesel and increase in crank angle was 1 degree. The CO and HC were expanded marginally in methanol blend when contrasted with neat biodiesel but NOx and smoke outflow were diminis hed in methanol – biodiesel blend. Thermal efficiency was increased by 4.1% by adding 10% methanol in biodiesel at 80% loading condition.

B. Tesfa et al.,[4] studied combustion and performance in diesel engine with biodiesel, used turbocharged diesel engine by utilizing bio diesel of waste oil, rapeseed oil, corn oil, and normal diesel. It was observed that BSFC and peak cylinder pressure had not significant differences by biodiesel. Higher cylinder pressure as compare to normal diesel, BSFC is approx. 15% higher than diesel.

Ertac.Hurdogan et al.,[5] investigated performance and emission characteristics of 4-stroke, 4-cylinders, direct-injected diesel engine running with different mixes of waste tire pyrolysis oil (WTPO) with diesel fuel. Fuel properties, engine execution, and exhaust emanation of WTPO and its mixes were analysed and contrasted with diesel. The trial comes demonstrated that WTPO diesel mixes showed comparative execution with diesel as far as torque and power yield of test engine. It examined that the mixes of pyrolysis oil of waste tire WTPO10 can productively be utilized in diesel engines with no motor alteration.

D H Qi et al.,[6] studied the performance, emission and combustion characteristics of a diesel engine utilizing rapeseed oil–diesel blends in two cylinder agriculture diesel engine. The main fuel properties of rapeseed oil (RSO) were researched and contrasted that of diesel. The test comes about noticed that viscosity and density of mixes were diminished and drawn nearer to that of diesel when RSO volume part was under 20%. At low motor loads, beginning of ignition for the mixes was relatively like that for diesel, however the pinnacle cylinder pressure and heat release rate were higher. At high motor loads, beginning of ignition for the mixes was somewhat sooner than that for diesel, however the pinnacle cylinder pressure and heat release rate were indistinguishable. For the mixes, there was somewhat higher BSFC and brake specific energy consumptions (BSEC) at low motor burdens. Smoke outflow was higher at low motor loads, however bring down at high motor burdens. NOx emanation was watched marginally bring down at low motor burdens and relatively indistinguishable at high motor burdens. CO and HC emanation were higher under all range of engine loads for the mixes.

M. Ebna Alam Fahd et al.,[7] A nitty gritty test concentrate to assess the effect of 10% water emulsion diesel (ED10) on engine performance and emission, and examination is made against base diesel fuel. Analysis performed in a 4-cylinder 2.5 L DI turbocharged Toyota diesel engine at four diverse engine stacking conditions (25%, 50%, 75% and 100% load). Motor speed was changed from 800 rpm to 3600 rpm in ventures of 400 rpm for each heap condition. Noticed that ED10 can deliver practically identical in-cylinder pressure and heat discharge rate like diesel. It was discovered that ED10 delivers marginally less motor power yield with higher BSFC, however bring down exhaust gas temperature and lower NOx discharge was experienced at all loads and motor speed condition for ED10 compared to diesel. Despite the fact that diesel engines are not inclined to higher CO outflow at medium to high engine load, it is discovered that ED10 experiences from higher CO emanation at low load and low engine speed condition. Nevertheless at higher motor speed for a specific load, the CO emanation diminishes fundamentally. The far reaching investigation of test comes about recommends that ED10 can possibly be considered as a focused inexhaustible and greener fuel for diesel engine applications.

L. Labecki et al.,[8] studied the emission and combustion characteristic of rapeseed oil mix in multi-cylinder diesel engine. Blends used were 10%, 20%, 30%,and 50% rapeseed oil in diesel fuel with varying infusion pressure and EGR 0% to 20%. Every one of these outcomes were analysed against diesel fuel under the reference engine working states of 2.7 bar BMEP at 1500 rpm, 800 bar of the infusion pressure, 0% of EGR and 9^0 bTDC of the infusion timing. At reference engine working conditions, the RSO and its mixes brought about a critical decrease of NOx emanation to the detriment of CO, HC, Smoke, and BSFC contrasted with diesel. The expansion in the infusion pressure brought down the soot emanation yet the NOx outflows for RSO and its blends brought about higher qualities than diesel. The EGR and infusion timing had the capability of decreasing the NOx emanation to the detriment of CO, HC and Smoke.

M.A. Kalam et al.,[9] investigated performance and emission of waste cooking oil in diesel engine. The waste cooking oil utilized such 5% palm oil with 95% customary diesel fuel (P5) and 5% coconut oil with 95% common diesel fuel (C5). B0 was utilizes for examination purposes. It was examined that there are diminishments in brake power of 1.2% and 0.7% for P5 and C5 individually contrasted and B0. In addition, decrease fumes outflows, for example, unburned hydrocarbon (HC), smoke, CO, and NOx is offered by the mixed fuels.

P.A. Davies et al.,[10] performance, combustion and emission analysis in multi- cylinder CI engine working on neat Jatropha and Karanj oils preheated by jacket water. There are little contrasts in the performance, emission and burning of Jatropha and Karanj oil outcomes.

Contrasted with fossil diesel, the BSFC on volume premise was around 3% higher for plant oils and the BTE was relatively comparable. Jatropha and Karanj task brought about higher CO_2 and NOx outflows by 7% and 8% individually, when contrasted with diesel. At full load, the plant oils gave around 3% higher pinnacle cylinder pressure than diesel. With the plant oils, aggregate heat discharge was littler at low load and relatively break even with at full load compared to diesel fuel.

J.H. Zhou et al.,[11] test investigation of performance, combustion, and emission parameter on diesel engine with ultra-low sulphur diesel (ULSD), palm methyl ester (PME), and a mixed fuel containing half by volume every one of the ULSD and PME, and normally suctioned hydrogen, at speed of 1800 RPM at various stacking conditions. Hydrogen was added to give 10% and 20% of aggregate fuel vitality. The accompanying outcomes are acquired with hydrogen expansion. Watched that there is little change in pinnacle cylinder pressure and pinnacle heat discharge rate. The effect on fuel usage and BTE is engine load and fuel dependent; being negative for the three liquid fuels at low motor loads yet positive for ULSD and B50 and irrelevant for PME at medium-to-high loads. CO and CO2 discharges diminish. HC diminishes at medium-to-high loads, however increments at low loads. NOx emanation increments for PME just however NO2 increments for the three liquid fuels. Smoke murkiness, molecule mass and number fixations are all together decreased for the three liquid fuels.

K. Rajan et al.,[12] have studied effects of EGR on diesel engine performance and emission by using sunflower oil. Used two cylinder water cooled diesel engine for investigation and different blends with diesel. The outcomes demonstrated that for a 7.5kW power output, B20 sunflower oil with 15% EGR rate produce 25% less NOx discharges compared to diesel for similar level smoke emanations.

W.M. Yang et al.,[13] have investigated Combustion, performance and emission qualities study of pine oil in a diesel engine. They observed BTE increases and BSFC decrease as increasing pine oil but CO, HC and Smoke level is reduced.

Haozhong Huang et al.,[14] experimentally investigated on spray, combustion and emission attributes of PO/diesel mixes in a multi-cylinder diesel engine. Made the mixes of 10%, 40%, 50% with diesel and use EGR. They conclude that output power increase as injection pressure, increase, this happens because of better atomization of fuel .The thermal efficiency will increase as increasing injection pressure. The quantity of CO and HC emanation decrease, with use of 0 to 24.6% EGR rate NOX emission decreases but When the EGR rate surpassed 24.6%, the soot, CO and, THC emissions sharply increased.

W,M Yan et al.,[15] studied perfect PO bio fuel in diesel engine. From the exploratory examination, however engine performance and emission, such as CO and smoke were observed to be better for PO with an inlet air temperature of 40 ^{0}C, the engine endured the difficulty of knocking because of postponed SOC (start of combustion). However, engine knocking was averted by the glow plug and preheating of inlet air and normal operation of engine was guaranteed. Observed that at an inlet air temperature of 60 ^{0}C, BTE was found to be standard with diesel, while emanations such as, CO and smoke were decreased by 13.2% and 16.8%, seperately, for perfect pine oil bio fuel at full load condition.

Natthanicha Sukasem et al.,[16] studied copy of fragmentary refining innovation for advancement of home developed pot refinery for ethanol refining. The modified distiller pot had higher efficiency of distillation than native pot. These were distilled ethanol concentration at 44.2 vol. %, 16.67 % of refined yield, for 159 min though local refining indicated 37 vol. % of refined ethanol, 15.33 % of refined yield and over 240 min.

Arkadiusz Jamrozik et al.,[17] studied effects of alcohol content in fuel mixture on performance and emission of a direct infusion single cylinder diesel engine fuelled with diesel-methanol and diesel-ethanol mixes. Volume percent of alcohol in the mixes ran from 0 to 40%. The expansion and the increment in the methanol substance of up to 30% in diesel-methanol mixes positively affected thermal efficiency of the engine however not a huge impacts on outflows of hydrocarbons and carbon dioxide. Additionally increment in volume percent of methanol of more than 30% caused unsettling influences in combustion process. On account of diesel-ethanol mixes, the enhanced work of test engine was watched for all alcohol content qualities. Engine efficiency expanded while keeping up the consistant level of indicated mean effective pressure. CO emanations were decreased, while THC and CO_2 emanations remained for all intents and purposes unaltered.

Ertan Alptekin et al.,[18] test investigation of ethanol and isopropanol as added substances with diesel fuel in a CRDI diesel engine. The alcohol fuels, for example, ethanol and isopropanol were utilizes as added substances with diesel fuel and two mixes (15% ethanol-85% diesel fuel, and 15% isopropanol-85% diesel fuel) were readied. The test motor was worked under three engine paces (1500, 2000 and 2500 rpm). From the exploratory outcomes, alcohol fuel mixes with diesel fuel caused higher BSFC values. Alcohol-diesel fuel mixes caused higher THC, NOx and CO discharges contrasted with pure diesel fuel.

Canakci et al.,[19] have studied experimental work to show effects of infusion pressure on performance parameter, combustion characteristics and tailpipe emission via using a methanol-diesel fuel varying from 0% -15% by volume. Results were taken by varying injection pressure to 180, 200, 220 bars at various burdens and 2200 rpm. At 200 bar result shows that heat release rate, maximum cylinder pressure, fuel conversion efficiency, smoke, THC and CO emanations were reduced with increasing the mass fraction of methanol, while an increment in BSFC and NO_X emanations have been observed. When injection pressure was 180 bars, NO_X emanations were decreased, whereas CO, THC, and smoke emanations were increased and other parameters remained unchanged. When injection pressure was 220 bar, CO, smoke, and THC emanations were decreased while heat release rate, most extreme cylinder pressure and NO_X emanations were increased. Considering BSFC and fuel change efficiency, optimum results were observed at an infusion pressure of 200 bars. From the trial information, it is clear that one can reduce NO_X on the verge of CO and THC, reduce CO and THC on the cost of NO_X.

Ciniviz et al.,[20] done experiments on diesel-methanol blend with 0% - 15% of methanol by volume on the engine, specified as four- cylinder, four-stroke, direct infusion, turbocharged and water cooled. They determined that NOx emanation was increased, on another hand, CO and THC emanation decreased as for diesel. Reduction in CO and THC attributed to an inherent oxygen substance of methanol, which prompts to the complete combustion. In addition, methanol molecule is polar. So, it cannot be devoured by any non-polar molecule, which leads lesser possibility of an unburned hydrocarbon. Moreover, increment in NO is understood by peak temperature achieved inside the ignition chamber.

W.M. Yang et al.,[21] examined combustion and emission analysis in diesel engine at incomplete load condition by utilizing biodiesel fuel, also Impact of load on performance, combustion and emission analysis. It observed that BSFC expanded somewhat at incomplete load condition.

Prashant et al.,[22] studied the exploratory examination to find an impact of diesel-methanol blend on combustion parameters. They were reported that when methanol percentage increments, ignition delay increases and most extreme rate of pressure rise also increases with peak pressure rise, compared with mineral diesel. They find maximum heat discharge rate when 40% methanol added with mineral diesel.

Yao et al.,[23] done experiments on diesel/methanol compound ignition framework to find out impact on emission with and without using an oxidation catalyst. They, also used fuel injector, through which homogeneous blend of air/methanol can be injected. Here, fueling system and strategies are diverse regarding injection of methanol. They concluded that high latent heat of vaporization attributed to bring down gas temperature hence, lower the NO_X emission. The result shows that smoke opacity can be reduced up to 50% with contrasted with traditional diesel and it can be reduced up to 80% with oxidation catalytic converter. The introduction of a methanol leads to lesser injection of diesel fuel thus, a decrease in a smoke obscurity of exhaust gas.

2.2 Conclusion from Literature Survey

In this work, several light oil bio fuels such as ethanol, methanol, and PO were classified under the classification of less gooey fuels and a detailed review on their method of activity in diesel engine has been made. Since the review on utilization of alcohol-diesel mixes has been managed as of now by numerous researchers, alternate procedures defined so far to make them achievable for their activity in diesel engine has been examined in the present work. However, for pine oil, an entire synopsis of their operational modes like using them in mixes with diesel/biodiesel and single fuel modes have been considered. Further, the engine qualities, for example, performance, combustion and emission for these less gooey fuels on various methods of activity have been delineated. From the broad audit work on less viscous fuels, it has been translated that these fuels could rise as a viable substitution of diesel in a diesel engine. The CO and HC emanation were diminished by using Diesel- Methanol blend due to inalienable oxygen content of methanol which lead to complete combustion. The smoke mistiness was reduced up to 50% with contrasted with customary diesel and can be reduced up to 80% with oxidation catalytic converter in diesel engine by utilizing diesel/methanol fuel. From the literature it was examined that less thick fuels are best alternative of diesel in Diesel engine because of its better atomization properties. Keeping these facts in mind, the present work has been emphasized on production of PO and its utilization in the CI engine for execution and emanation characteristics.

2.3 Research Objective

In the light of the after soul, the present investigation was undertaken to complete depth study relating to performance and emission attributes of an engine fuelled with diesel and mixes of PO. The work has been isolated into following phases

- Extraction of pine oleoresin from pine tree by tapping process.
- Steam distillation of Pine Oleoresin for the production of PO.
- To characterize the physicochemical properties of the PO.
- To study the performance and emission characterises of a CI engine utilizing diesel, and various mixes of distilled PO with diesel (P10, P20 and P30).

- Analysis of experimental data relating to performance and emission characteristic, its graphical representation and finding the optimal percentage of biodiesel mix in diesel. Keeping in mind the end goal to achieve above objective following methodology way employed.

2.4 Present Research Methodology

In this part, pine oil (PO) was investigated in blended fuel mode in order to envisage the behavioural qualities in a diesel engine and formulate the basic trend with which engine performance, emission is obtained.
For the current study, the distillate PO has been procured from Green Pine Industry Bhagwanpur Roorkee. Different blends of distilled PO with diesel such as P10 (10 vol. % PO mixed with 90 vol. % diesel), P20 (20 vol. % PO mixed with 80 vol. % diesel) and P30 (30 vol. % PO mixed with 70 vol.% diesel) were prepared by stirring mixtures to keep the blend integrity. Finally, prepared blends are tentatively researched in a single cylinder diesel engine without modifications. The performance and emission parameters, for example BSFC, BTE, EGT, CO, HC, smoke and NO_X were analysed with varying load at constant speed. Before beginning the analyses with the revealed mixes of PO, engine was made to keep running for 30 minutes with diesel in order to achieve an enduring state and make typical working temperature condition. After the trial the base fuel was totally emptied out of tank, pump and fuel lines and supplanted by various mixes of PO which are prepared for testing. Further, before monitoring the results, the lubrication oil and cooling water temperature were noted to ensure whether the motor has reached warm up condition. The motor was stacked from 0 % to 100 %, dynamically in the means of 20% by controlling current provided to the eddy current dynamometer. Since the motor being utilized is a consistant speed engine, worked at 1500 rpm, fuel pump is changed to accordance with keep up the steady speed at different stacking conditions. Everyone of the reading, relating to engine experimentation and examination, were noted down at encompassing conditions, when engine was balanced out and has achieved unfaltering state condition. The tests are rehashed for three times and average of all three readings were taken, consolidated and utilized for estimation to improve exactness with the result obtained.

III. RESEARCH METHODOLOGY

3.1 Pine Oil - An Overview

Pine oil biofuel is a renewable biomass based source of fuel. It is exceptional in feedstock originates from the forest and can be mixed with petroleum base diesel fuel. It is directly extracted from pine tree by the process of tapping. It may obtained by steam distillation of stumps, needles, twigs and cone from an assortment of type of pine. Pine tree are found in the Himalaya between an elevations of 1000-1900 meter. The hill stations are Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. Production in India is approximately 25000 tons per annum. The interest for PO by 2022 is anticipated to be 53894 tons in the whole world. The other pine oil producing countries are China, Indonesia, Portugal, Brazil and Russia. The color of PO is light yellow in color and has a crisp woodland smell. It is utilized as a part of wide assortment of utilizations including as a flavour and scent in pharmaceuticals, as a dissolvable, disinfectant and antiperspirant, for the buoyancy of lead minerals and in textile scouring. There are three unique kinds of PO known as gum, wood and sulphate pine oil, each are delivered from various parts of pine tree and have their own properties. Among of them gum PO is much significant and most used crude material for synthesis, it is called pine oleoresin. Apparently, a pine tree can deliver an average of 2.75 kg of pine oleoresin, in which oleoresin there is about 20% turpentine and 65% rosin, and the turpentine present in it is then additionally prepared to deliver pine oil.

3.2 Production of Pine Oil

3.2.1 Pine Tree

A Pine Tree is a evergreen, coniferous resinous type of Tree. It develops from a Pine Cone. A legitimately planted Pine Cone has roughly a 20% shot of developing to following stage every day. The middle time to development is around 18 days, with more than 90% of seeds developing in 32 developing days.

Pine Trees outside the ranch can be slashed down or tapped. These trees will respawn as Stage 3 saplings (20% possibility every day) and develop as ordinary from that point forward, as long as stump is expelled.

On the off chance that a tree or other things are straightforwardly adjacent, the tree won't develop to maturity, yet stops at stage four. Once completely developed, things can be set beside the tree without influencing it antagonistically. Trees can be planted beside stones, lakes, precipice edges and even the nursery and still develop to full maturity gave they are not by another tree. Pathing, for example, cobblestones have no impact on tree development.

It is directly extracted from pine tree by the process of tapping. It may obtain by steam refining of stumps, needles, twigs and cone from an assortment of types of pine.

The steps involves in tapping process used are appeared in figure 1 and 2. The crude material for delivering PO is oleoresin, which is gathered independently from pine tree by process of tapping. To being with, the oleoresins are first washed and put in a reactor, encompassed by cylindrical coils, which encourages the supply of hot steam. After the entry of steam, oleoresins are isolated into rosin and turpentine vapours, the last is then sent into a condenser and liquid turpentine was gathered. The turpentine independent from anyone else is bio oil, containing low boiling fraction compounds such as α- Pinene and β-pinene as its significant constituents. After partition of low bubbling fraction compounds from oleoresins, rosin is deserted as a deposit, which has the characteristics of camphor. To synthesize pine oil, turpentine is permitted to react with ortho-phosporic acid and toward the finish of the reaction PO is gathered as an essential oil.

The steps to collect PO from stumps, needles, twigs and cone of different types of pine are such-

Initially, CST is separated from wood chips. This unrefined item is then sent to additionally preparing, during this period the turpentine is refined to isolate the α-pinenes. The α-pinene is sold as is, and the α-pinene converted to pine oil in two further process steps.

3.2.2 Tapping Process

Extraction of turpentine from the wood chips are either 'cooked' in a group or a consistant process, the strategy of turpentine extraction varies relying upon technique used. In the clump procedure turpentine is acquired by venting the digester and afterward isolating the fibres and dark alcohol from water and turpentine in a violent wind separator. In the nonstop procedure less turpentine is acquired, despite fact that procedure is still monetarily viable, and this time water and turpentine vapour is gotton by flashing dark alcohol twice.

The vapor blend is then channeled to a condenser and afterward to a partition tank, where the fluid and turpentine phases isolate because of their density distinction. The fluid undercurrent is funneled off, and the CST overflow is likewise channeled off to storage tanks. Due to corrosive impacts of CST, funneling and storage tanks are made of mild steel, and all other parts of stainless steel. The various non – condensable are passed to a scouring segment where they are purified of unfortunate compounds by acidic solution (to form non-volatile salts).

Figure 1. Tapping Process

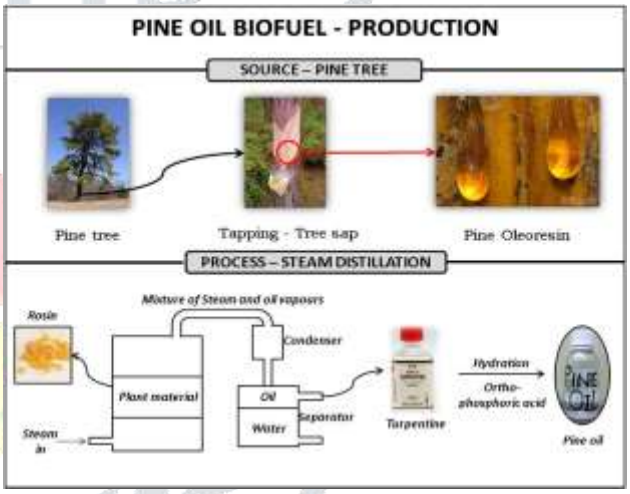

Figure 2. Production of Pine Oil

The vapor blend is then channeled to a condenser and afterward to a partition tank, where the fluid and turpentine phases isolate because of their density distinction. The fluid undercurrent is funneled off, and the CST overflow is likewise channeled off to storage tanks. Due to corrosive impacts of CST, funneling and storage tanks are made of mild steel, and all other parts of stainless steel. The various non – condensable are passed to a scouring segment where they are purified of unfortunate compounds by acidic solution (to form non-volatile salts).

3.2.3 Crude Sulphate Turpentine (CST)

Pine oleoresin is bottomless wellspring of useful terpenes. It has two noteworthy parts: turpentine, which is the volatile division, and rosin, which is the solid portion. A key component of tree guard, oleoresin is a vital non-wood ranger service item on account of different ordinary and potential uses of its terpenes. Oleoresin subordinates can be managed by various enterprises, including pharmaceutical, cosmetic, and food industries, as well as by chemical industry in production of different items, for example, paint, varnishes, cements, bug spray, and disinfectants. Biotic and abiotic factors that influence oleoresin production can be utilized to enhance yields by advancing particular signalling and biochemical barrier pathways. Oleoresin production systems and the industrial applications of this complex blend of natural products are analysed in this chapter.

The CST plant is a batch operation. A pot associated with a distillation segment is loaded with unrefined turpentine and a vacuum drawn while the energize is warmed to point where lightest compounds start to bubble off. These "heads" are of no usage as they contain for the most part water and light sulphurous compounds, and they are sent to an incinerator. Once these heads have been driven off, temperature can be expanded and vacuum intensified. As the pinenes bubble off the reflux ratio can be expanded to enhance level of detachment accomplished in the segment. The distinction in volatility between α(alpha) and β(beta) structures is adequate to allow very great detachment by distillation, however to guarantee product quality in least distillation time a little intermediate cut of blended α and β pinene is taken. These intermediate cuts are put away until the point that adequate is held to make up a group for redistillation. Following the gathering of the pinenes, the buildups can be expelled from the pot and new charge of turpentine conceded. Overall time for a group distillation is around 20 to 24 hours.

A commonplace charge would be about 15 m^3 of turpentine containing 35% α-pinene and 55% β-pinene. Refining is affected at a pressure of around 50 Torr and temperature of up to 150º C and produces four cuts as takes after, in addition to a residue which would be around 10% of charge:

- Heads cut - the first fraction, comprising to a great extent of water and sulphureted hydrocarbons in addition to some α-pinene. This cut is refined with a reflux ratio of 30:1 and is around 3% of charge.
- α-pinene - around 20 - 25% of the charge, recouped at a reflux proportion of 14 to 30:1.
- Intermediate - α and β pinenes in proportion of 1:2. This cut is around 20% of charge and is refined with a reflux proportion of 30:1.
- β-pinene - 40 - 45% of the accuse of a reflux proportion of in the vicinity of 5 and 10:1.

α and β pinenes recouped from the refining are held in stock tanks. Beta pinene is sent out in mass ship loads while alpha pinene is managed as the part of following phase of the procedure.

3.2.4 Pine Oil Production (steam distillation)

Alpha pinene recouped from the CST distillation is 96% α- pinene, 3% pinene and 1% camphene. To influence unrefined PO to PO, the α-pinene is changed over to blend of α-terpineol (PO ingredient), dipentene (an isomer of pinene), unreacted pinene and some minor amounts of other results and polluting influences. The conversion of α-pinene to pine oil, of which the major segment is tertiary alcohol α-terpineol, includes hydration of carbenium ion. Further hydration of α-terpineol will yield terpin, or on other hand the α-terpineol can be dehydrated to dipentene. The terpin may experience incomplete dehydration to α-terpineol and different terpineols. Alternatively the α-pinene may likewise experience isomerisation to camphene or thermal isomerisation to dipentene. As two pinenes are easily interconverted using certain acids, bases and hydrogenation catalysts, α-pinene in distillation fraction can be converted to similar final products.

Table 2 Properties of α- pinene and β- pinene

Properties	α- pinene	β- pinene
Chemical formula	$C_{10}H_{16}$	$C_{10}H_{18}O$
Molar mass	136.24 g·mol−1	136.24 g mol-1
Density (at 20 °C)	0.858 g/Ml	.872 g/Ml
Melting point	−62.80 °C	−61.54 °C
Boiling point	156.85 ± 4.00 °C	165–167 °C
Solubility in water	less soluble	Insoluble
Appearance	Colourless	Clear liquid

The pinene hydrolysis reaction yield is dependent on both time and temperature. An expansion of either will cause a higher transformation of α-pinene, however would likewise expand the extent of pinene changed over to dipentene. As PO is favoured item, the reaction conditions are controlled to limit loss of pinene to dipentene. In the PCNZ procedure the pinene is hydrolysed utilizing aqueous phosphoric acid at temperatures upto 70^0C for 3 hours. The immiscible liquids are disturbed enthusiastically in a cluster reactor and little measures of surfactant can be added to advance great interphase contact. Under these conditions the reaction yield is required to be:

- Unreacted pinenes and camphene 55%
- Dipentene10%
- Pine oil 30%
- Residue (terpin and hydrate) 5%

After reaction the response mass is washed free of acid and afterward washed with caustic to neutralise any remaining free acid, before distillation.

3.3 Pine Oil Composition and Properties

Pinene ($C_{10}H_{16}$) and Terpineol ($C_{10}H_{18}O$) are major constituents of PO. Unlike methanol and ethanol, the alcohol group present in PO was noted to be terpineol, a tertiary alcohol, and the presence of pinene in it makes some differences to its quality. However, alike to lower alcohols, such as ethanol and methanol, pine oil (terpineol) has carbon, hydrogen and oxygen atoms in its subatomic structure, Chemically PO is an alicyclic hydrocarbon and from its subatomic structure, it is marked that it has bring down sub-atomic weight and shorter carbon chain length than creating as an inexhaustible wellspring of fuel in the territories of other alternate fuels, diesel or biodiesel. In addition, it could be concluded that PO includes inbuilt oxygen within its structure that is relied upon to enhance the combustion process. Pine oil has lower carbon to hydrogen (C/H) ratio, allowing complete and smokeless combustion. The lower molecular weight, inherent oxygen, shorter carbon chain length and presence of double bonds of PO biofuel are believed to have an impact on its fuel properties.

3.4 Properties and Its Measurement

3.4.1 Density

Definition - It is defined as the ratio of mass per unit volume.

Density = mass/ volume

In present study density is measured by automatic densitometer. Method used is ASTM D4052. The automatic densitometer is shown in figure below-

Table 3 Specification of Apparatus

Measuring range	Density Temperature Pressure	0 to 3 g/cm^3 -10 to +200 ^{0}C 0 to 500 bar
Accuracy	Density Temperature	Up to .0001 g/cm^3 .03 ^{0}C
Repeatability standard	Density	Up to .00005 g/cm^3
Additional information	Dimensions Weight	510*330*230 mm 27.1 kg

Fuel density is generally increase with increasing atomic weight of fuel molecules. Density mainly affects fuel atomization, more density require more power to pump it from fuel tank that decrease the overall performance due to pump losses, Pumps and injectors must convey the right measure of fuel for proper combustion. As per EN14214 standard it has range of 850-900kg /m^3.

3.4.2 Kinematic Viscosity

Definition- Viscosity is a measure of a fluid resistance to flow. It depicts the interior friction of a moving fluid.

A fluid with large viscosity resist motion because its subatomic makeup gives it a lot of inner rubbing and injection do not perform properly. Lower viscosity increment the fuel evaporation rate and blending with air, good atomization with fuel. On other hand too low viscosity can cause oil to no lubrication enough. It is determined by ASTM D445 test technique, by this method it should in the range of 2-6cSt at 40 ^{0}C.

Figure 3 Density Meter

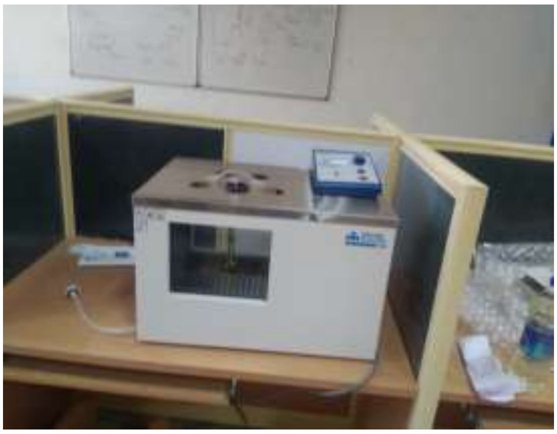

Figure 4 Viscometer

3.4.3 Flash Point

Definition- Flash point of fuel is lowest temperature at which it ignite when give an ignition source. Flash point is some time might be mistaken for auto ignition temperature which is the fuel vapour ignite without any ignition source. In this study it is measured by Abel closed-cup method: EN ISO 13736 (ECS, 2008 Standard).

This apparatus measures flash point within range of 15 to 70 ^{0}C.

Outline Method- Cool the sample no less than 17 ^{0}C underneath the normal flash point. Fill the fuel in oil-cup up to the index, apply heat to external shower so as the temperature of the sample in oil-cup ascends at the rate of 1^{0}C per minute, and stir sample in oil-cup in clockwise course to give downwards thrust of 30 rpm. When temperature of sample reaches at 9^{0}C beneath the normal flash point, start applying test flame at every 0.5^{0}C rise in temperature. Record temperature at which distinct flash occurs.

3.4.4 Calorific Value

Definition- calorific value of fuel is thermal energy released per unit amount of fuel when the fuel burned completely and results of ignition are cooled back to the underlying temperature of combustion mixture.

When the product of combustion are cooled to 25 ^{0}C practically all water vapour resulting from combustion process is condensed, the heating value so obtained is known as higher or gross calorific value of fuel.

Lower or net calorific value is the heat discharge when water vapour in the results of ignition isn't condensed and stays in vapour form. The calorific value can measured by bomb calorimeter.

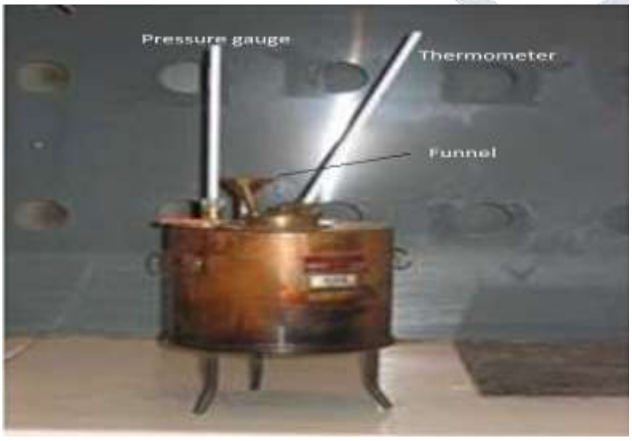

Figure 5 Abel closed–cup flash point apparatus

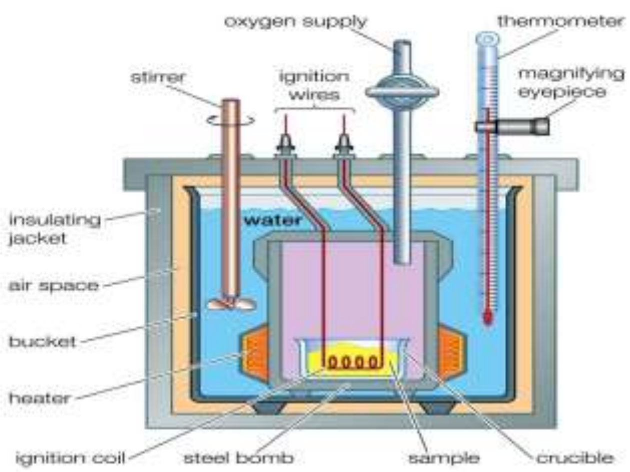

Figure 6 Bomb Calorimeter

Outline method

Weighed amount of fuel is placed in the silica crucible. Crucible is bolstered over the ring.

A fine magnesium wire contacting the fuel test is extended over the electrodes.

Oxygen supply is constrained into bomb until a pressure of 25-30 atm is reached.

Starting temperature of water in calorimeter is noticed after through stirring. The current is switched onn, fuel in crucible consumes with development of heat.

The heat created by consuming of fuel is exchanged to H_2O which is mixed all through the test by the electric stirrer.

Maximum temperature appeared by thermometer is recorded.

Calculation:

WT=HM

Where,

W= Water Equivalent, of a substance is equivalent to measure of water needed to absorb same measure of heat as that substance does for one degree of increase in temperature(Cal/˚C).

T= Temperature rise in ˚C.

H= Calorific Value in Cal/gm.

M= Mass of Sample in gm.

3.5 Experimental Test Rig

Engine used for experimentation is a stationary diesel engine of Kriloskar make, running at a consistent speed of l500rpm. This engine, which is commonly a generator set, is said to be utilized for marine, agricultural and other industrial applications and is regarded to produce most extreme power yield of 5.2kW. Typically, this normally suctioned diesel engine possesses a cylinder, cylinder head, piston, bowl in piston combustion chamber and other.

Table 4 Specification of Engine

Type	4-stroke, Kirloskar make, direct injection constant speed ,vertical and water cooled engine
No of cylinder	1
Bore	87.5mm
Stroke	110mm
Compression Ratio	17.511
Rated power	5.2 kW
Rated speed	1500
Dynamometer	Eddy current
type of injection	Mechanical pump-nozzle injection
Start of injection	23° BTDC
Injection pressure	220 bar
Lubricating oil	SAE4O

The engine being utilized is a 4-stroke engine and operates on a standard diesel cycle. Initially, air is sucked through inlet manifold, after filtering it in air filter, during the suction stroke. To turn away any fluctuations with air flow, an infusion tank was deployed in the complex, which capably damps out the throb created by engine. By this measure, suction pressure was looked after steady, encouraging constant flow of air through the inlet manifold. After suction stroke, air is compressed in combustion chamber with the compression proportion of 17.5, which is supposedly the default value. Likewise with the instance of heat engine, heat produced by consuming of fuel is changed over into valuable piston work in the expansion stoke and remaining heat is lost through cooling water and exhaust. In exhaust stroke, the fumes gases are expelled out through exhaust manifold and various managed emissions, for example, HC, CO, CO2, NO_X and smoke were measured during the experimentation. For maintenance, lubrication oil SAE 40 has been utilized for the lubrication of engine components, so as to prevent the wear and tear of engine in long term.

Finally, the engine which is water cooled has separate connections for supplying and returning of cooling water from a water sump.

3.6 Measurements

3.6.1 Power Measurement

Engine is loaded by the eddy current dynamometer, which has been generally used to quantify power yield of engine. Notably, this dynamometer comprises of stator and rotor. The stator is surrounded by electromagnets and rotor has been directly coupled to engine crankshaft. Generally, current is gone through electro magnets and when the rotor rotates, an opposing electromagnetic force is generated and it induces a resistance to the rotor. To vary the load applied to engine, current provided to the electromagnets is varied by an electronic controller and thereby, different opposing forces are produced. This force (F), which is applied on the dynamometer, is measured by a strain gauge and subsequently, the torque (T) is computed by multiplying the measured force signal and the separation from centre of the shaft to pivot point of strain gauge (R),
$T=R\times F$

Following the calculation of torque, the power developed by engine can be evaluated if speed at which motor operates is known. In our case, the speed is computed by magnetic pick up principle, wherein, a toothed wheel is placed near the engine shaft and the pulse produced by it is noted as speed. Since the motor being utilized for current research work has been kept at steady speed of 1500 rpm, the BP at this speed can be figured as follows,

$B= (2\pi NT/60)\times S$ kW

Where, T is torque in N-m, N is rotational speed in rpm and S is dynamometer constant.

3.6.2 Fuel Consumption Measurement

The fuel flow rate was estimated on volume premise utilizing a burette and stop watch. As needs be, time taken for combustion of 10cc of fuel (t) was noted and with this, the total fuel consumption (TFC) or flow rate of fuel can be ascertained as follows,
$TFC = (\rho v/t)$ g/s

Where, ρ is density in g/cm^3, v is volume of fuel consumed in cm^3 ($v=l0\ cm^3$) and t is time in seconds. In order to enhance accuracy of the readings noted, measurements were repeated for three times and finally, the average value of three readings was taken for calculation. Amount of fuel required to produce l kW power output, which is called BSFC, has been estimated as follows,
$BSFC = (TFC\times 3600/BP)$ g/kWhr

The BSFC determines performance of engine and from which, efficiency of engine, which appraises the potential to convert vitality released from fuel to useful power, can be calculated.

The BTE is defined as ratio of power developed by engine to heat input i.e. the heat energy supplied by the fuel. Accordingly, BTE of engine can be deduced from the following expression,
BTE = BP/Heat input

Heat input to engine has been resolved from mass of fuel consumed (TFC) as follows,
Heat input = TFC × CV
Where, TFC is total mass of fuel consumed in g/s and CV is the calorific value of fuel in kJ/Kg.

3.6.3 Emission Measurement

Regulated emissions, for example, HC, CO, CO_2 and NO_X were estimated utilizing AVL 444 di-gas analyser on dry basis. These discharges are estimated utilizing emission analyser based on NDIR (non-dispersive infra-red) rule by specific absorption. The fumes test to be assessed was gone through a cool trap (dampness separator) and filter component to prevent water vapor and particulates from going into analyser. Typically, HC and NO_x were estimated in parts per million (ppm) and CO, CO_2 and O_2 emissions were estimated in tens of percentage volume. Smoke level was estimated in hartridge smoke unit (HSU) utilizing a standard AVL 437 C smoke meter. The smoke is estimated in view of the standard of light extinction rule wherein, measure of light hindered by the sample of fumes gas from diesel engine is estimated in terms of smoke obscurity.

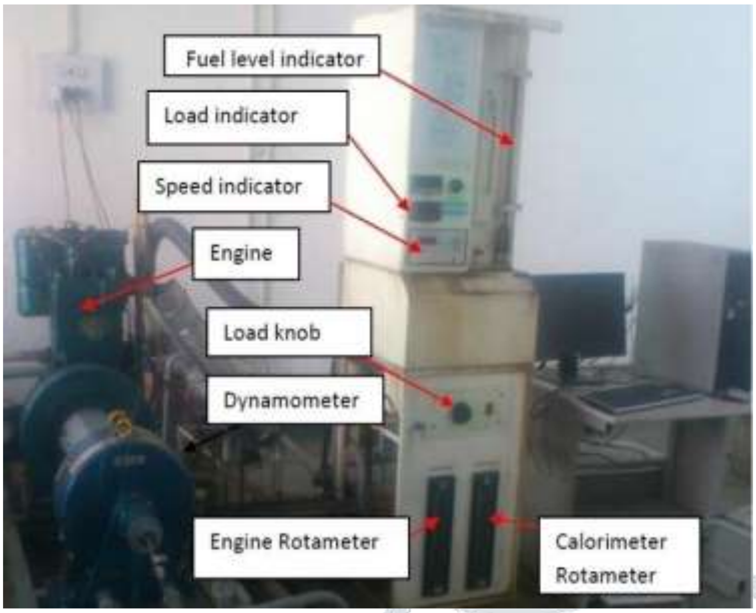

Figure 7 Diesel Engine Setup

Figure 8 Smoke Meter

IV. RESULT AND DISCUSSION

4.1 Overview This chapter discusses result of all the tests performed for investigation of performance and emission attributes of a single cylinder diesel engine working on mixes of PO and diesel.

4.1.1 Comparison of Pine Oil with Petro-diesel and Biodiesel

The produced pine oil (PO) has been characterized as per ASTM/EN Standards as shown in Table 5. The properties of obtained PO has been contrasted with petro-diesel and biodiesel to explore their merits and demerits. The PO has lower kinematic viscosity, boiling point and flash point than that of conventional petro diesel, which is bound to enhance vaporization, atomization and mixing with air. Adding to this, PO was indicated to have comparable calorific value with diesel. Thus, similar power output or fuel consumption are expected. However, the latent heat of vaporization and self-ignition temperature of PO are slightly higher than diesel, it may affect auto-ignition temperature. In addition, cetane number of PO is lower than diesel and biodiesel, which is generally a result of shorter carbon chain length; bringing about poor ignition quality and this is additionally declined by its higher self-ignition temperature. Therefore, it is required to give some start support for fruitful activity of it in diesel engine like mixing them with higher cetane fuel, adding ignition promoters, preheating inlet air or operating it in dual fuel mode. The cold flow properties, for example, pour point and cloud point were found to be lower than diesel, because PO has lower kinematic viscosity. Besides this, the other properties, for example, acidity, carbon buildup, copper strip erosion, sulphur and ash content are found to be consistence with principles and fit in with use of PO as appropriate alternative fuel in diesel engine.

Table 5. Properties of distilled pine oil compared with diesel and biodiesel ASTM/EN standards

Properties	**Diesel fuel**	**Pine oil**	**Biodiesel ASTM standard D6751**
Cetane no	40-55	38.9	47-65
Density (kg/m^3)	850	874	880
Low heat value (kJ/kg)	42000	40916	39000 – 41000
Boiling point (^{0}C)	260	188	315-350
Flash point (^{0}C)	57	60	93
Stoichiometric ratio	14.3	10.25	11
Latent heat of vaporization (kJ/kg)	265	380	-
Kinematic viscosity at 40 ^{0}C (cSt)	3.09	1.7	1.9 -6

Carbon (wt. %)	87	77.4	77
Hydrogen (wt. %)	13	11.1	12
Oxygen (wt. %)	0	11.5	11

It is clear from the Table 5 that combustion of PO will induce complete combustion due to its low kinematic viscosity, which improves atomization property of fuel. Higher oxygen content in PO reduces CO emissions because by the oxidation of CO into CO_2. In order to eradicate or curb out pollution from our environment, PO has more edge than biodiesel and this statement can be validated by **Table 5** as exhaust emission expected to be less in PO as compare to biodiesel. As per table 5 it is expected that PO has longer ignition delay than diesel and biodiesel as cetane number of PO is lower. Carbon, hydrogen and oxygen content of PO is almost similar to biodiesel.

4.2 Performance Analysis

In this section, engine performance in terms of BTE, BSFC and exhaust gas temperature (EGT) of various PO blends were analysed and compared with petro-diesel.

4.2.1 Brake Thermal Efficiency (BTE)

Figure 9 represents the BTE of PO. As the load increase, the BTE increases. It can be seen from figure 9 that over the whole engine load, pine oil mixes (except P20) have comparable BTE compared with diesel. At low to medium loads, P20 blend has marginally higher BTE compared to diesel, whereas at medium to higher load, comparable BTE was seen compared with diesel. Moreover, P10 has comparable BTE compare to diesel at all loads. Lastly, P30 blend has lower BTE compared to diesel and different mixes. The higher BTE in P20 blend is generally a result of lower kinematic viscosity and higher oxygen content that improve the atomization and enhanced the combustion process, accordingly higher BTE. The PO has slight lower calorific value compare to diesel. Thus, slight drop in BTE was seen in P30 mixes as compared to other mixes.

4.2.2 Brake Specific Fuel Consumption (BSFC)

Figure 10 shows BSFC of pine oil blends compared with diesel fuel. It can be watched from figure 10 that over the whole engine load, pine oil mixes have higher BSFC compared with diesel. At lower loads (except 0% load), lower BSFC was observed in case of P20 blend compared with diesel and other pine oil mixes, while at higher burdens, all the PO mixes have higher BSFC compared to diesel. The higher BSFC of PO mixes compared with diesel are generally a result lower calorific value than that of diesel.

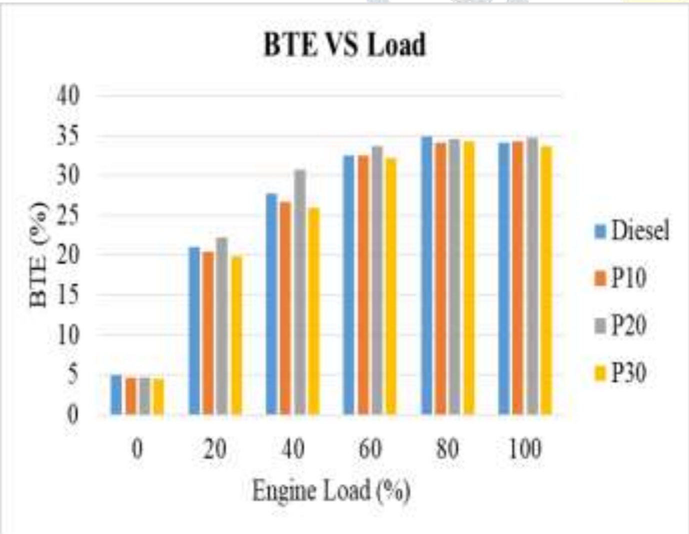

Figure 9 BTE of PO Blends vs. Engine Load

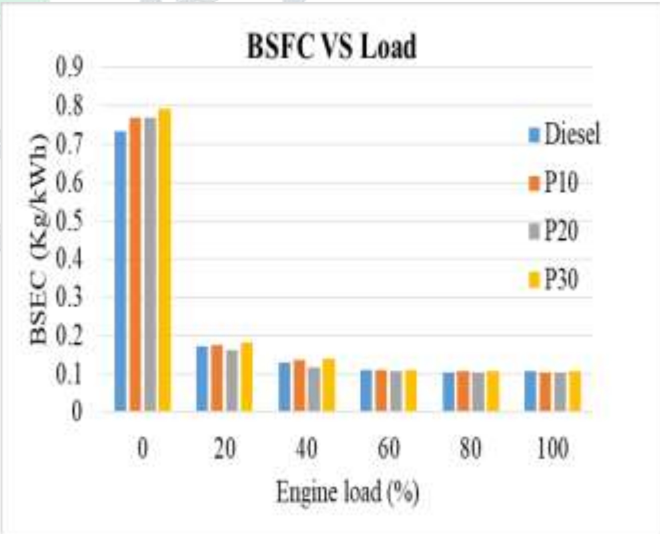

Figure 10 BSFC of PO Blends vs. Engine Load.

4.2.3 Exhaust Gas Temperature (EGT)

Figure 11 represents the EGT of PO blends compared with diesel. Generally, EGT indicates that loss of useful heat energy after combustion process. There is reverse connection of EGT with BTE. The higher EGT indicate that major proportion of useful heat vitality gets wasted during combustion process, whereas lower EGT is an indication that maximum percentage of heat vitality is utilized for the power output and leads to complete combustion inside cylinder. It can be watched from figure that over the whole engine load, pine oil mixes have lower EGT compared to diesel. P10 blend has higher EGT compared with other pine oil mixes, whereas P30 mix has lower EGT compared to other pine oil mixes.

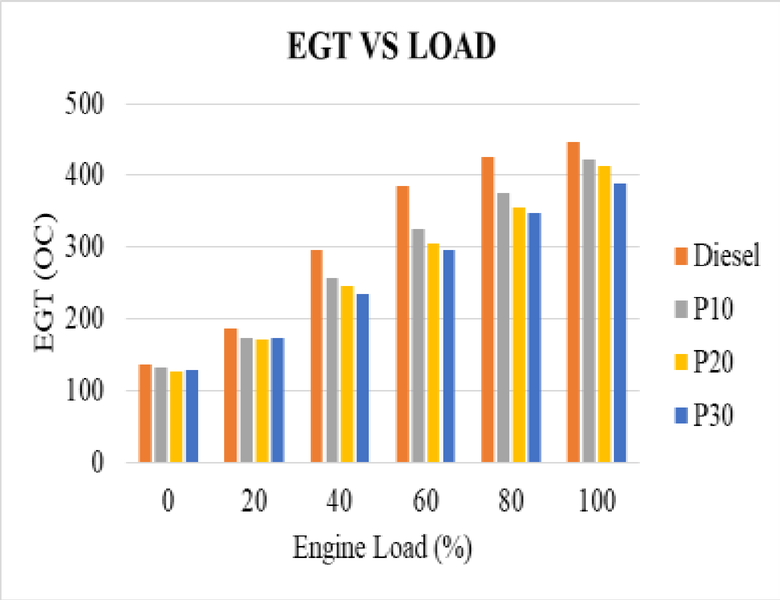

Figure 11 EGT of PO Blends vs. Engine Load.

Here, reasons for lower EGT in case of PO mixes are different. The PO has higher latent heat of evaporation compared to diesel. Thus, it absorbs some measure of heat vitality and cause cooling impact. Therefore, decrease in EGT. It can be watched from graph that as percentage of PO increases in diesel, the EGT get decreases compared to diesel.

4.3 Emission Analysis

4.3.1 CO Emission

Figure 12 represent the CO emission of PO mixes compared with diesel. The CO discharges generally represents incomplete combustion or limited supply of oxygen i.e. in light of lack of oxygen in combustion procedure. The inadequacy of oxygen does not permit oxidation of CO into CO_2 due to inadequate combustion. It can be watched that P10 and P20 blends have lower CO emanations compared to diesel, whereas P30 mix has slight higher CO emanations compared to other blends but lower than that of diesel fuel. The reasons for lower CO emanations in pine blends are essentially higher oxygen content compared to diesel. Thus, lower emanation of CO is a direct result of the way that produced CO has been converted (oxidation) into CO_2 by reacting with extra oxygen show in the molecule of PO. In addition to this, lower kinematic thickness of PO additionally prompts better atomization and more efficient combustion. Thus, lower CO emissions.

4.3.2 HC Emission

Figure 13 represent the unburnt hydrocarbon of PO mixes compared to diesel. UHC emissions generally represents incomplete combustion.

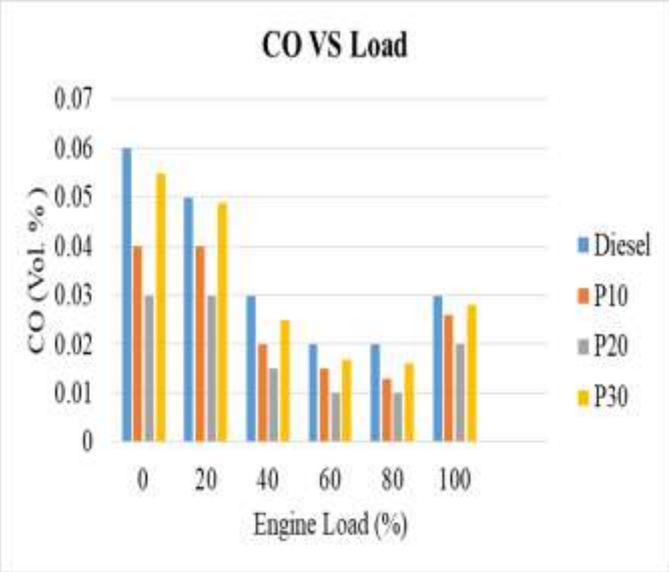

Figure 12 CO Emission of PO Blends vs. Engine Load.

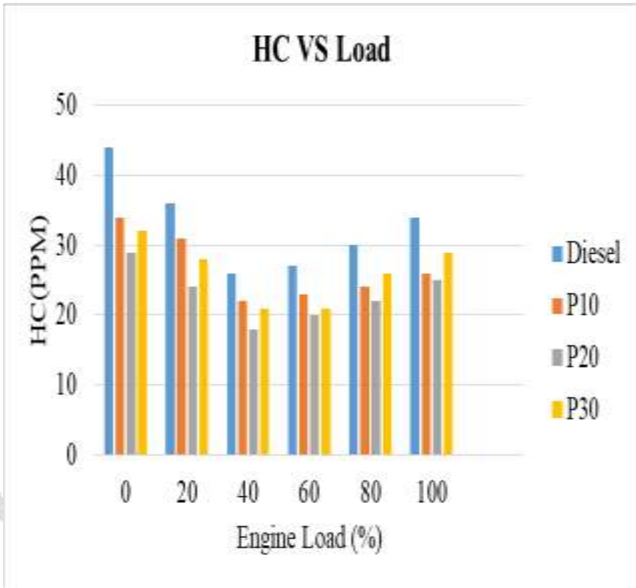

Figure 13 HC Emission of PO Blends vs. Engine Load

It can be watched from the figure that as the load increase, the UHC emissions decreases. P10 and P20 blends shown lower UHC emanations compared to diesel, whereas P30 blend shown higher UHC emissions compared to other pine oil mixes but lower than diesel fuel. The reasons for lower UHC emanations in P10 and P20 blends are predominantly because of effective combustion compared to diesel and P30 blend.

4.3.3. NOx Emission

Figure 14 depicts NOx emanations of PO compared with diesel fuel. Generally, NO_X formation take placed at high temperature because nitrogen and oxygen react at high temperature to form oxides of nitrogen (NO_X). The NO_X emissions are observed in the form of either NO or NO_2.

It can be watched from figure that as the load increases NOx emanation increases. The pattern of NO_X emanations for different pine oil mixes and diesel fuel are appeared in Figure 14. At bring down loads, lower fuel utilisation and over-lean fuel- air mixing results in lower in- cylinder temperature, which realizes lower NOx emission at these loads. When engine is working at high load conditions, a higher NO_X outflow level is observed. It can be watched that PO mixes have lower NOx emissions compared with diesel. It can be watched that P10 blend has higher NOx emanation compared with other PO blends. As percentage of PO increases in diesel fuel, NOx emanation gets decreases. The reasons for lower NOx emissions is predominantly because of higher latent heat of evaporation which causes cooling effect. Thus, cylinder temperature gets lowered. As a result, lower NOx emissions compared to diesel fuel.

4.3.4 CO_2 Emission

Figure 15 portrays the CO_2 emanation of PO mixes compared to diesel fuel. It can be watched from figure that as load increases, the CO_2 emissions increases. The CO_2 emissions indicate the quality of combustion. Higher CO_2 emission reflected complete combustion whereas bring down CO_2 emissions indicates the incomplete combustions. It can be watched that PO mixes have lower CO_2 emanations compared to diesel fuel. The P20 blend showed the higher CO_2 emanation compared to other pine oil mixes. Thus, more efficient burning of air-fuel charge was occurred in P20 blends compared to other pine oil mixes. The lower CO_2 discharge of PO can be linked with latent heat of evaporation because some measure of heat vitality has been absorbed and causes cooling effect. Thus, lower CO_2 emanations compared to diesel.

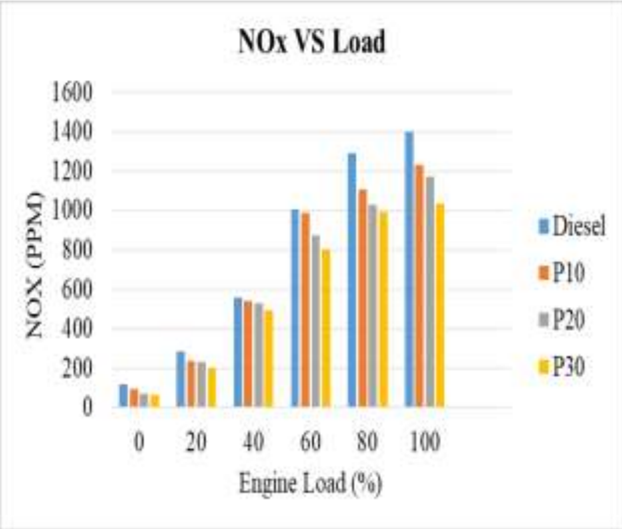

Figure 14 NOx Emission of PO Blends vs. Engine Load

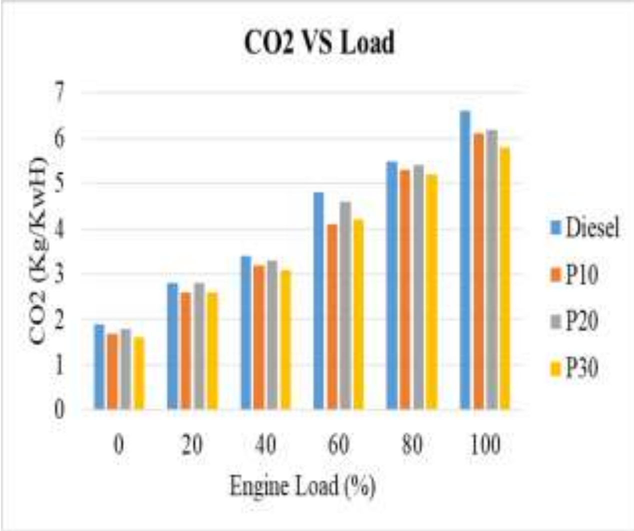

Figure 15 CO_2 Emissions of PO Blends vs. Engine Load

V. CONCLUSIONS AND SCOPE OF FUTURE WORK

5.1 Conclusions

The current experimental investigation indicates that PO can be directly used in blended form with diesel without trans-esterification on account of its fascinating properties. Engine performance and emission test were conducted on diesel, pine oil mixes (P10, P20, and P30) with the help of diesel engine test rig, AVL smoke meter and AVL gas analyser. From all experimental observation it has concluded that:

- Physiochemical properties of PO are found so close to petro-diesel.
- P20 blend showed higher BTE with comparable BSFC compared to diesel, whereas P10 and P30 blends have comparable BTE with higher BSFC compared to diesel.
- EGT of all PO mixes are lower than that of diesel fuel.
- All PO mixes have bring down CO emissions compared to diesel fuel, whereas P20 blend has highest reduction in CO emissions.
- All PO mixes have bring down UHC emissions compared to diesel fuel, whereas P20 blend has highest reduction in UHC emissions
- All PO mixes have lower NOx emissions compared to diesel, whereas P30 blend has lowest NOx emissions compared to diesel.
- All PO mixes has bring down CO_2 emissions compared to diesel fuel.

It has been concluded that PO based P20 blend can be used as a partially substitute fuel for petro-diesel without adjustment in the CI engine with better performance and emissions characteristics.

5.2 Scope of Future Work

- The combustion and emanation analysis of PO mixes can be performed in multi-cylinder diesel engine.
- Can check effects of PO bio fuel blend with methanol on performance and emission in a Diesel engine.
- Emission decrease from a diesel engine fuelled by pine oil biofuel utilizing SCR and catalytic converter.
- Impact of ignition advancing added substances on the attributes of diesel engine controlled by PO-diesel blend.
- Effect of infusion pressure and infusion timing on performance and emission qualities of PO blends.

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NOMENCLATURE

ASTM	American Society of Testing and Materials
BSFC	Break Specific Fuel Consumption
BTE	Break Thermal Efficiency
BMEP	Break Mean Effective Pressure
EGT	Exhaust Gas Temperature
CO	Carbon monoxide
CO_2	Carbon dioxide
cSt	Centistokes
CV	Calorific Value
HC	Hydrocarbons
UHC	Unburnt Hydrocarbons
NO_x	Nitrogen Oxides
SO	Smoke Opacity
PO	Pine Oil
RPM	Revolution Per Minute
EGR	Exhaust Gas Recirculation
BP	Brake Power
CST	Crude Sulphate Turpentine

VI. ACKNOWLEDGEMENT

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