EXPERIMENTAL AND OPERATING CHARACTERISTICS OF PINE OIL - DIETHYL ETHER – DIESEL BLENDS IN DI DIESEL ENGINE

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Abstract

The present work aims to analyze the solubility, performance and emission characteristics of pine oil-diethyl ether blends in single cylinder four stroke turbocharged VCR diesel engine. The turbocharger retrofitted in a diesel engine is used to improve the boost pressure and compressed airflow inside the engine cylinder. The viscosity and cetane number of pine oil is lower than that of diesel and improved by addition of diethyl ether by 5% (Vol.).The result shows that the BSFC and BTE for turbocharged engine is higher than that of normal diesel operated engine. The HC, CO and smoke emission for pine oil-DEE blend with diesel are reduced significantly than that diesel fuel alone.

Key words: Pine oil, Turbocharger, Diethyl Ether, Diesel, VCR Engine.

1. Introduction:

The demand for fossil fuel stringent emission norms leads to the researchers and engineers have concentrate on their attention to search as alternate fuels and adopting various techniques in diesel engine that improves the performance and reducing the emissions [1]. The pine oil is a new renewable source of alternate fuel which extracted from pitches of pine tree having improved physical and chemical properties which gives optimistic emission impact to the atmosphere [2]. The pine oil and kapok oil gives lower hydrocarbon, carbon monoxide and smoke emissions nearly 8% to 18%compared with diesel [3]. The phase separation behavior of biodiesel with diesel is the main drawback due to density variation and different viscosities [4]. The performance like BSFC and BTE get improved in proportion of pine oil in cylinder injection at preheated condition [5]. The solubility and phase behavior of diesel-biodiesel was analyzed using liquid crystalline structure at various temperature [6].The High speed diesel engine (HSDI) was used to analyze the three different diethyl ether/ diesel fuel blends. The NO_x and CO emission for DEE/diesel blend were lower and higher HC emission was observed than that of diesel fuel [7]. The diesel with 5% diethyl ether, 25% biodiesel and 70% diesel gives lower BSFC compared to that of neat diesel and reduction in smoke opacity but at the expense of higher NO_x emission [8-9]. The IC engines waste and their abundance of energy through exhaust gases, can be reused through turbo compounds, thermoelectric generators and Rankin bottoming cycles which reduces fuel consumption and CO_2 emission. The turbine efficiency shows a very significant role to recuperate waste heat into energy, so turbine design is very critical in turbo compounding [10-11]. Decreasing the inflexible emissions and increasing the performance and high fuel intake, were speed up the introduction of new turbo equipment to improve boost pressure [12]. The waste gate turbocharger with varying injection pressure leads to better improvement in the performance and lower in HC, CO and NO_x emissions [13].

The combined variable geometry turbo charging and EGR also reduces 2.1% of fuel consumption, 50% of NO_x emission and 22.8% particulate matter respectively [14]. The EGR is one of the effective technology to reduce drastic amount of NO_x emission by 60% and 41-53% of CO_2emission [15]. The variable nozzle turbo charging is new concept where the NOx emission was reduced up to 58-66% and BSFC was decreased up to 5-9.5% at low speed [16]. The inlet swirl generator device was used to test the turbo and flow velocity characteristics based on CFD approach [17]. The main objective of biodiesel is to replace the few percent of fossil fuel by improving density, calorific value and viscosity [18-19]. The similar characteristics of biodiesel with diesel the CO and smoke for biodiesel is lower compared with diesel [20]. From the above it is proposed to use pine oil is to improve the performance of the engine, along with DEE in the turbocharger engine.

Therefore in this present work an attempt has been made to investigate the performance and emission characteristics of the pine oil blends with diesel in a turbocharged diesel engine. Physical properties of the pine oil is much closer to that of diesel and also it does not need any fuel processing like transesterification or pyrolysis since its viscosity is much closer to that of diesel. Further the cetane index of the pine oil is poor when compared to that of diesel and to improve the cetane index of the biofuel DEE is added. The experimental setup has been provided with turbo charger to boost the mass of air fed into the combustion chamber which leads to increase in the pressure and thereby enhance the combustibility of low quality fuel successfully.

2. Material and Methods:

2.1. Pine oil

Pinus is the scientific name of pine which is the sole genus in the subfamily pinoideae and the species of Pinus is pine seed. The new renewable pine oil which is derived from the seeds by distillation process and purify with acids. The pine oil have structure ofterpineol $C_{10}H_{18}O$ and pinene $C_{10}H_{16}$. The properties of pine oil were compared with diesel, ethanol and diethyl ether and were shown in Table 4. The pine oil has lower boiling point, viscosity and flash point than that of diesel which improves better atomization and flame propagation. Further when compared with the ethanol and methanol, pine oil have greater calorific value which gives heating value nearer to alcohol fuel and also suitable alternate fuel for diesel, The test fuel nomenclature used in the study were shown in Table1.

2.2. Solubility testing of fuel:

Solubility is the important property of fuel to form a homogenous solution in all proportion of fuel blends. The phase separation characteristics and fuel properties of the diesel- pine oil – diethyl ether are

Test Fuel Nomenclature	
Normal Diesel Engine	Turbocharger Not connected with Engine setup
D75P20DEE5	75% Diesel + 20% Pine oil + 5% DEE
D55P40DEE5	55% Diesel + 40% Pine oil + 5% DEE
D35P60DEE5	35% Diesel + 60% Pine oil + 5% DEE
D15P80DEE5	15% Diesel + 80% Pine oil + 5% DEE
D5P20DEE5	95 % Pine oil + 5% DEE

Table 1 Test fuel nomenclature

Tested. Initially the blend is kept in glass vial and sealed tightly for perceiving the physical appearance. The same method is trailed out with other properties of diesel, pine oil and DEE. Each component is varied from 0% to 100% by volume in 20% increments to form sample mixture. In this study, the phase behavior of the three components is investigated and shown in Figure 1. The solubility properties of diesel biodiesel and diethyl ether were shown in Table 2.

Fig 1 Test of Diesel, Biodiesel & Diethyl Ether

Table 2 Physico chemical properties of biodiesel blends and diesel

Sample No.	Diesel %D	Pineoil %P	%DEE	Cetane Index	Flash Point (°C)	Boiling Point (°C)	Density (kg/m^3)	Heat of Combustion (kJ/kg)
1	75	20	5	48.45	67.95	260.73	827.02	42280
2	55	40	5	40.25	59.05	234.73	837.64	42300
3	35	60	5	32.05	54.65	208.73	848.26	42320
4	15	80	5	23.85	50.25	182.73	858.88	42340
5	0	95	5	17.7	46.95	163.23	816.40	42355

2.3. Turbocharger:

The recent development in turbo charging technology plays a very important role in engine operating characteristics. The turbocharger provides high pressurized air flow at low engine speeds and higher efficiency at high pressure ratios. The variable geometry turbocharger (VGT) and two stageturbocharging systems have been established to attain high power concentration with better fuel economy. In this present work, the turbocharger connected with VCR DI diesel engine which can improve the air boost pressure at various load conditions and the turbocharger specification is given in Table 4.

Fig 2 Turbocharger setup in Engine

Table 3 Turbocharger specifications

Turbocharger Specification	
Maximum Pressure ratio	3.3
Maximum Speed	120 ×10^{3}RPM

Maximum allowable gas temperature	1382°C
Air flow rate	5.5-24 m^3/min
Materials (Compressor & Turbine)	high-nickel "Ni-Resist"
Compressor wheel diameter	Internal : 51.20 External : 71 Trim : 52
Turbine Wheel Diameter	Internal : 53.90 External : - Trim : 76
Cooling System	Oil Cooled

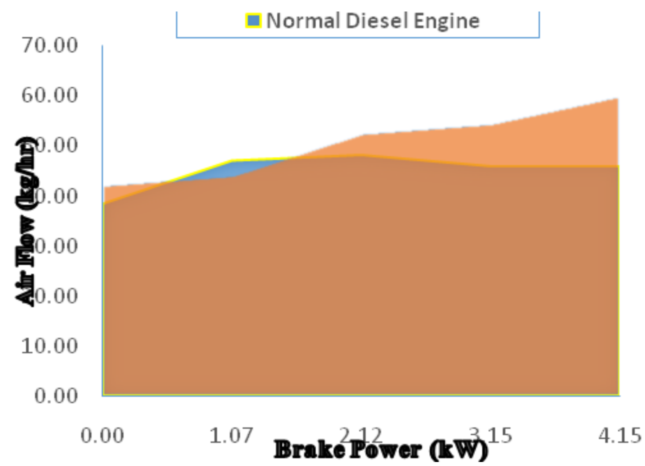

Fig 3Brake power Vs Air flow

Fig 3 shows variation of air flow with brake power for normal diesel engine and turbocharged diesel engine. It is seen from the graph that the turbocharged engine gives higher air flow at maximum loads. At no load condition the air flow for normal engine and turbocharged engine are 38 kg/hr and 42 kg/hr respectively. The air flow is maximum for turbocharged engine compared to thatof normal engine. This is became of higher air flow produces better combustion and flame front inside the cylinder results in lower carbon monoxide and hydrocarbon emission.

Table 4 Properties of Fuel

Property	Diesel	Pineoil	DEE (Diethyl ether)
Density (kg/m^3)	822	875.1	710
Kinematic viscosity (m^2/s)	3.6×10^{-6}	1.3×10^{-6}	0.23×10^{-6}
Flash point (°C)	74	52	-49°C
Boiling point (°C)	180-340	150-180	34.6
Calorific value (kJ/kg)	42700	42800	33900

Sulfur content (%)	Less than 0.025	Less than 0.005	-
Calculated cetane index	52	11	145
Latent heat of vaporization (kJ/kg)	265	300	360
Auto-ignition temperature (°C)	250	300	160
Stoichiometric air to fuel ratio	15	14	11.19
Molecular structure	$C_{12}H_{23}$	$C_{10}H_{18}OH + C_{10}H_{16}$	$(C_2H_5)_2O$

Turbocharger

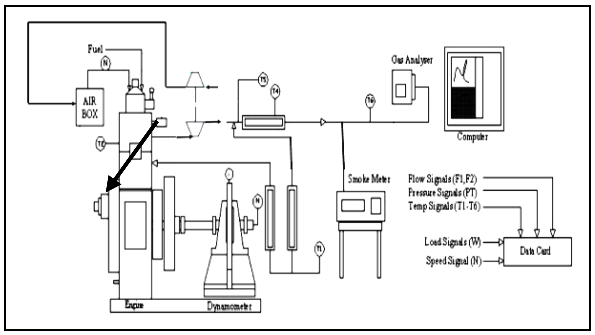

Fig 4 Engine and data acquisition system

The inaccuracy and uncertainties are expected to evolve based on the testing condition, The accuracy of the equipment, atmosphere, standardization and comment of readings. The uncertainty of the engine apparatus's and the related instrumentation has been shown in Table 6.

Table 5 Experiment Uncertainties

Parameters	**Systematic Errors (±)**
Speed	± 2 rpm
Load	± 0.2 N
Time	± 0.1 s
Brake power	± 0.12 kW
Temperature	± 2°
Pressure	± 1 bar
NO_x	± 10 PPM
CO	± 0.01%
CO2	± 0.01%
HC	± 4 PPM
Smoke	± 2 HSU

Experimental setup and testing procedure:-

Table 6 Engine Specification

Engine Specification	
Engine Make& Model	Kirloskar &SV1
Type	Single cylinder, 4 stroke
Cooling system	water cooled
Power	power 5.9 kW (8 BHP)
Stroke	110 mm
Bore	87.5 mm
Compression ratio	17.5:1
Capacity	661 cc.
Pressure	220 bar

2.4. Experimental setup:-

Exhaust Gas Analyzer:

An AVL digas analyzer is used to measure the exhaust gas composition. The brief specification of exhaust gas analyzer is given below in Table 8.

Table 7 DI gas Analyzer

Exhaust Gas analyzer Specification	
Manufacturer	AVL private limited
Type	AVL 444 di gas Analyzer
Ranges	CO - 0 to 10 % HC - 0 to 10000 PPM NO_X - 0 to 5000 PPM

Fig 5 Schematic diagram of smoke meter and five gas Analyzer

3.2. Experimental Procedure:

The cooling water and fuel supply of the test engine is checked for any leakage. The engine is started at no load condition and speed is calibrated to 1800rpm by adjusting fuel supply system. The experimental test is conducted at different load conditions with various biodiesel blends. The five gas analyzer used to analyze exhaust gases such as carbon monoxide (CO), unburnt hydrocarbon (HC) and oxides of nitrogen (NO_x). Further, the smoke meter is used to measure the smoke emission in the exhaust. A computer is connected with engine using for data acquisition system (DAC) which plots the graph drawn automatically according to engine readings.

3. Results and discussion:

3.1. Performance Characteristics:

3.1.1. Brake Specific Fuel Consumption (BSFC):

Fig 6 shows the variation of BSFC with brake power for various proportions of pine oil diethyl ether diesel blends of turbocharged engine and normal diesel engine. It is observed that the BSFC decreases with increasing BP at all loads. Among the different proportions, BSFC of D80P20is 0.02 kg/kW-hr lower than that of other blends and normal diesel engine. This is due to the moderate calorific valve and high air flow in the engine properties of pine oil are diesel, resulting in lower BSFC

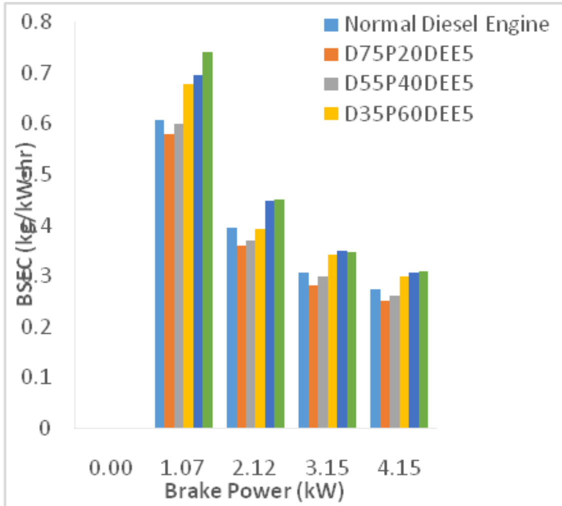

Fig 6 Brake power Vs Brake specific fuel Consumption

3.1.2. Brake Thermal Efficiency(BTE):

The variation of BTE and brake power for various properties is shown in Fig 4.1.3. It is observed that the BTE increases with increasing BP at all loads. Among the different proportions, the BTE for D75P20DEE5 is increased by 4% than that of diesel. This is due to the calorific value of pine oil and DEE was nearly equal to diesel which gives better heating value and improved performance. Further the turbocharger supports higher air flow and complete burning of the fuel inside the cylinder leads to higher BTE.

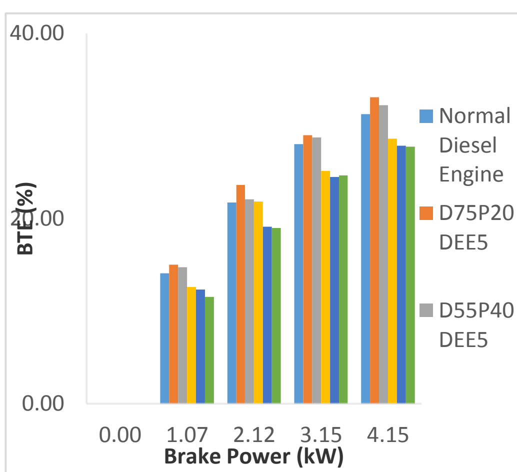

Fig 7 Brake power Vs Brake Thermal Efficiency

3.1.3. Exhaust Gas Temperature (EGT):

Fig 8 shows the variation of EGT with brake power for different proportion of pine oil diethyl ether – diesel blends and normal diesel engine. It was observed that the EGT increases with increasing brake power at all loads. The EGT for D80P20 is 127ºC and 10% lower than that of diesel engine. The lower EGT should improve the performance of the engine and influences better combustion process. This may be due to better combustion, longer ignition delay, and higher turbo boost pressure and air flow. The reduction in energy losses for all the pine oil biodiesel blends in exhaust also reason for lower EGT.

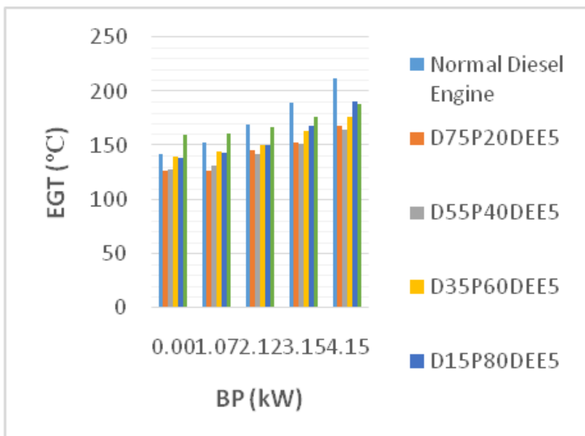

Fig 8 Brake power Vs Exhaust gas Temperature

4.2. Emission Characteristics:

4.2.1. Carbon Monoxide Emission (CO)

When the presence of rich air in the combustion, the product is mainly CO_2 similarly the partial oxygen supply inside the cylinder only half the oxygen united with carbon which results in formation of carbon monoxide. In the present work,the turbocharger supplies suitable amount of compressed air into the engine which gives lower CO emission. Fig shows the variation of brake power with carbon monoxide for different proportions of pine oil diethyl ether – diesel blends and normal diesel engine. Among the different proportions, the CO emission for D80P20 is decreased by 10% than that of diesel engine. This is due to complete combustion and higher oxidation of COto CO_2.

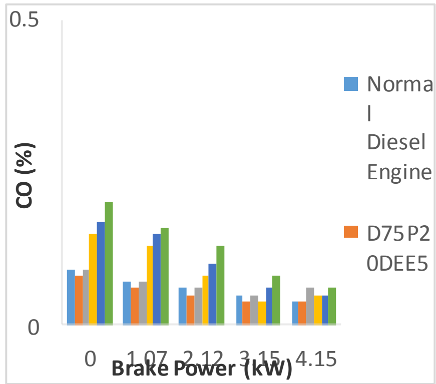

Fig 9 Brake power Vs Carbon Monoxide

4.2.2. Unburned Hydrocarbon Emission (HC)

The turbocharger supplies compressed air and provides better oxidation for combustion and lean mixture formation and thereby leads to reduction in HC emission. Fig shows the variation of HC emission with brake power for different proportions of pine oil diethyl ether – diesel blends and normal diesel engine. It was observed from the Fig 11 that the HC emission decreases with increasing BP at all loads. Among the different proportions, the HC emission for D80P20 is decreased by 22% than that of normal diesel engine at maximum load.

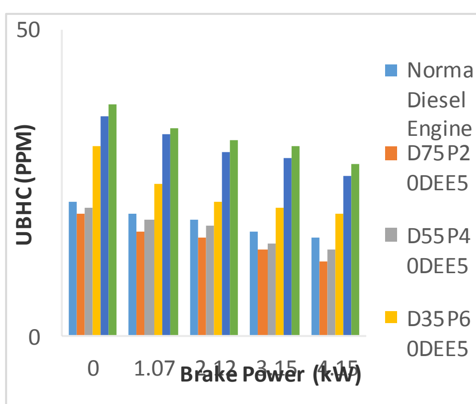

Fig 10Brake power Vs Unburned Hydro carbon

4.2.3. Oxides of Nitrogen Emission (NO_x)

Fig 12 shows the variation of NO_x emission with brake power for different proportions of pine oil diethyl ether – diesel blends and normal diesel engine. It was observed that the NO_x emission increases with increasing brake power at all loads. Among the different proportions, NO_x emission for D80P20 is 5% lower than that of normal diesel engine. At lower load the amount of fuel being injected is higher and oxygen supplies is lower, for this variation the turbocharger supplies maximum amount of compressed air to the inlet manifold makes lean burning and reduces the NO_x formation for all blends at lower loads. However at higher loads the NO_x formation gradually increases due to high flame temperature, in the combustion chamber.

4.2.4. Smoke

Fig 12 shows the variation of smoke emission with brake power for different proportions of pine oil diethyl ether diesel blends of turbocharged engine and normal diesel engine. It was observed that the smoke emission increases with increase in brake power at all loads. Among the different proportions, the smoke emission for D80P20 is decreased by 12% than that of normal diesel engine at maximum load. This is also due to better atomization and complete solubility of biodiesel and leads to reduction in smoke emission.

5. Conclusion:

The following conclusions are drawn from the present experimental investigations.

The BSFC for D80P20 is decreased by 6% than that of normal diesel engine, Further the BTE for D80P20 and D60P40 is increased by 4% than that of normal diesel engine. The exhaust gas temperature is decreased by 10% than that of normal diesel engine.

The HC, CO and smoke emissions for D80P20 bends is decreased by 10%, 22% and 52% respectively than that of normal diesel engine.

The NO_x emission is decreased by 5% when compared that of normal diesel engine.

Hence it is concluded that the pine oil became a better alternate fuel for diesel at lower blending ratio in terms of performance and emission characteristics without addition of DEE and incorporation of turbocharger.

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