Experimental Investigation of NOx Emission from Eucalyptus-Antioxidants Blends Powered DI Diesel Engine

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Abstract
Using green fuel in diesel engines reduces release of exhaust gas although several researchers said green fuel releases high percentage of NO_X in diesel. The Diesel is depleting in the world as the consumption of the fuel is high. The research is find out the effect of using a mixture of Eucalyptus methyl ester in diesel engine along antioxidants on release of toxic gas from the engine and engine effectiveness. The experiments have been conducted using concentrations of varied antioxidant of Eucalyptus bio fuel mixtures (100, 250, 500, 1000ppm). The output shows that Pyridoxine Hydro Chloride is better in reduce the release of NO_X compare Tert Butyl Hydro Quinone and Di-Ethyl Amine.

Keywords: Eucalyptus oil, Antioxidant, Engine emissions, Green fuel, emission.

Introduction
There has been significant growth in population and living style. People have started to use vehicles more as there are changes in the living style hence the consumption of fuel also has increased. Fuel is used mainly in two sectors to generate electricity and for transportation. The unstable demand the fuel is much more efficient than gasoline. Globally the lookout for an alternate fuel to diesel and petrol has been rising to reduce the hazardous effect caused by diesel and petrol. But, the green fuel causes higher level of NO_X release in contrast to diesel [1]. NO_X affects health and causes pollution. Research on release of NO_X from green fuel is lesser in contrast to research conducted on release of NO_X from diesel [2].

Resisting the green fuel oxidation is the method to lessen its effect without modifying the fuel features. Using antioxidant in the fuel retards the green fuel degradation process[3]. Main antioxidants are free radical terminators. Peroxide decomposers are minor antioxidant. This process is initiated by eliminating oxidative catalyst and prohibits the starting process oxidation. Antioxidants used for this process are phenolic and amine[4].

To extend the life of the substrates and obstruct oxidation antioxidant are blended to oxidizable material [5]. It has been without modification the release of smoke, HC, NO_X in contrast to the diesel fuel with Tert-butyl hydroquinone [6]. The blending of antioxidants soybean green fuel. It discovered the NO_X emission lessened by 9.23% with a forfeiture of 9.06% and 10.42% augments the release of CO and HC [8]. The main idea of this experiment is to find out the NO_X emission by suing the Eucalyptus green fuel blends.

Material and Methods
To perform the investigation Kirloskar model diesel engine 5.9 kW. Fig. 1 shows a diagrammatic representation of the experimental setup. Overhead cooling water tank has been used for using water required to cool the engine. The Fuel consumptions are calculated by use of digital stopwatch, burette level. A burette with a two-way valve has been used to passed by the fuel tank in to diesel.

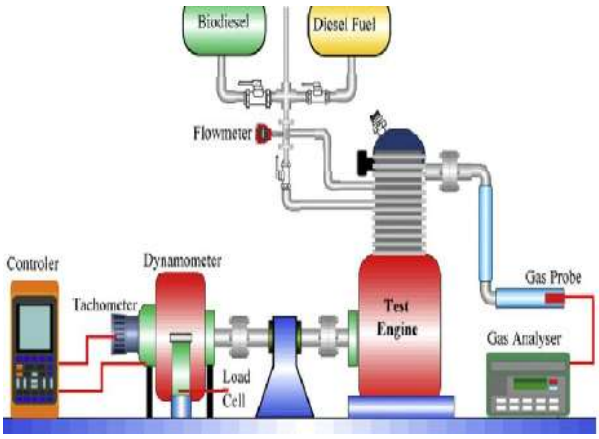

Fig. 1: Experimental setup

Thermocouple contributes to measure temperature at different locations. The piezoelectric transducer has been implemented in the engine to calculate combustions process. Release of exhaust is measured with a gas analyser. The exhaust gas are hydro carbon, NO_X and volume in percentage of carbon monoxide, carbon dioxide and oxygen. table 1 and table 2 shows the Engine Specification and Instrument uncertainty.

The experiments have been done using varied antioxidants with Eucalyptus fuel blends, diesel. The antioxidants PHC, TBHQ and Di-Ethyl Amineare exactly checked use ofa electronic weighing balance and added to Calculate amount of Eucalyptus bio fuel. Thehomogenous blends (antioxidant and fuel) prepared by rpm 4000 speed mixer. AVL smoke meter used to measured by smoke. Table 3 and 4 lists the properties of tested fuel and antioxidants. The load levels 20% intervals noted by the performance, emission, combustion parameters.

Table 1
The Engine Specification

Parameters	Specifications
General	4 stroke, single cylinder, water cooled, kirloskar model
Stroke(mm)	110
Bore(mm)	87.5
Cubic capacity (lit)	0.661
Power (kW)	5.9
Compression ratio	17.5 : 1

Table 2
The Instrument uncertainty

The Parameter	Percentage of Uncertainties
Brake power	± 0.4
BTE	± 1
SFC	± 1.4
NO emission	± 1.6
CO emission	± 1.3

Table 3
The Properties of Fuel

Properties	Diesel	Eucalyptus
Density (kg/m^3)	0.8356	0.902
Calorific value (kJ/kg)	43,623	39,268
Kinematic viscosity (cst)	2.2	2.74
Flash point (^{0}c)	75	102
Cetane Number	50	48

Results and Discussion

Impact of antioxidants additives on emissions and depth of smoke has been studied and with all experiments discussed in this research. The release of exhaust gas from the engine has been impacted by blended antioxidant in the eucalyptus bio fuel. Engine effectiveness and release of antioxidant eucalyptus fuel blends and eucalyptus fuel are talked about in the following sections.

Table 4
The Properties of Antioxidants

Antioxidants	CAS number	Molecular weight (g/mol)	Melting point
Di-Ethyl Amine	108-88-6	73.04	-52 ^{0}C
Pyridoxine Hydro Chloride	59-54-0	205.46	213 ^{0}C
Tert Butyl Hydro Quinone	1947-34-0	165.4	125 ^{0}C

A. The NO_X emissions: NO_X is the most harmful pollutant that is released during the Ignition stage. The cause of NO_X formation is high level of ignition temperature, lengthier period of ignition within the combustions[9]. A representation in table 5 and table 6 denote a percentage reduction in NO_X of varied antioxidants blend with E100 and E20 fuel at different load conditions. Blend of Antioxidants E20 decrease with three / fourth load 5.8%.

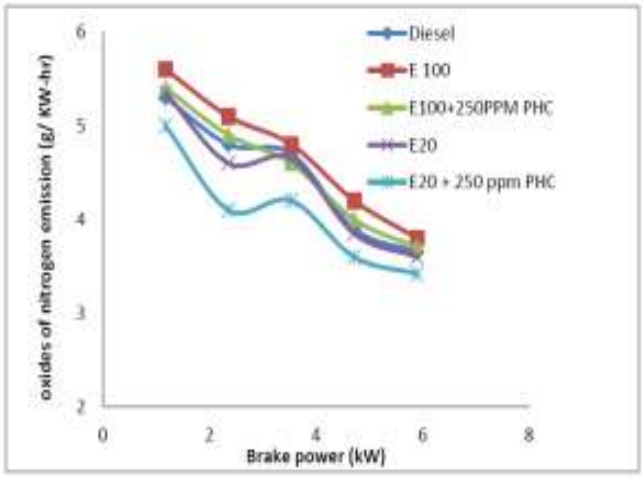

Fig. 2: Variation of NO Vs Brake power with various Blends

Antioxidant concentration does not affect the antioxidant activity. By using E100 fuel, there has been minimum release of the harmful gas to the extent 18.2%, 14.8% and 16.8%, on loading the fuel with PHC, THQ, DEA. PHC is the efficacious antioxidants, reducing more than 20% of NO_X with Varied engine load. Using E20 fuel, the release of NO_X by using Pyridoxine Hydro Chloride additive and base fuel to the extent of 80% load had been 2.13 & 2.31 g/kW hour. Using E100 fuel the release of NO_X 4.3 & 2.86 g/kW hour.

Fig. 2 depicts that there is higher release of NO_X than the conventional diesel fuel. NO_X formation starts by reactions of hydrocarbon with molecular nitrogen [11]. The higher production of CH radicals while green fuel ignition steers for higher NO_X formation while using green fuel.

The impact of adding antioxidants additive in green fuel had its impact on release of CO is illustrated in Fig. 3. CO formed when insufficient supply of air at less temperature [12]. The release of CO was high on increasing the percentage of antioxidants. The block dues to antioxidants over the conversion of CO to CO_2 lead to high release of CO.

The load of 80%, the level of Pyridoxine Hydro Chloride additive had been around 6.1% and 10.34% leading to higher release of CO in contrast to neat B20 and eucalyptus fuel. Nevertheless the release of CO by adding antioxidant was lesser than petro-diesel [13].

Table 5
Reduction in no emissions phase-I

Brake Power (kW)	100ppm			250ppm			500ppm			1000ppm		
	E20+ PHC	*E20+ TBHQ*	*E20+ DCA*	*E20+ PHC*	*E20+ TBHQ*	*E20+ DCA*	*E20+ PHC*	*E20+ TBHQ*	*E20+ DCA*	*E20+ PHC*	*E20+ TBHQ*	*E20+ DCA*
0	0	0	0	0	0	0	0	0	0	0	0	0
1.18	3	5	4.2	5	10.0	7.0	11	21	18.0	17.5	14	16.0
2.36	3.1	5.3	4.4	5.2	10.2	7.2	11.2	21.2	18.2	17.6	14.2	16.2
3.54	3.3	5.5	4.6	5.4	10.4	7.4	11.4	21.4	18.4	17.8	14.4	16.4
4.72	3.6	5.7	4.8	5.6	10.6	7.6	11.6	21.6	18.6	18.0	14.6	16.6
5.9	3.8	5.9	5.0	5.8	10.8	7.8	11.8	21.8	18.8	18.2	14.8	16.8

Table 6
reduction in NO emissions phase-II

Brake Power (kW)	100ppm			250ppm			500ppm			1000ppm		
	E100+ PHC	*E100+ TBHQ*	*E100+ DCA*	*E100+ PHC*	*E100+ TBHQ*	*E100+ DCA*	*E100+ PHC*	*E100+ TBHQ*	*E100+ DCA*	*E100+ PHC*	*E100+ TBHQ*	*E100+ DCA*
0	0	0	0	0	0	0	0	0	0	0	0	0
1.18	0.9	1.2	0.95	2.3	2.9	2.6	4.0	4.5	4.5	5.1	5.5	5.2
2.36	0.92	1.3	1	2.5	3	2.7	4.1	4.7	4.7	5.2	5.6	5.3
3.54	1.0	1.4	1.1	2.6	3.2	2.9	4.2	4.8	4.8	5.3	5.7	5.4
4.72	1.1	1.5	1.2	2.8	3.4	3.1	4.3	4.9	4.9	5.4	5.8	5.5
5.9	1.2	1.6	1.3	2.9	3.8	3.3	4.4	5.1	5.1	5.5	5.9	5.6

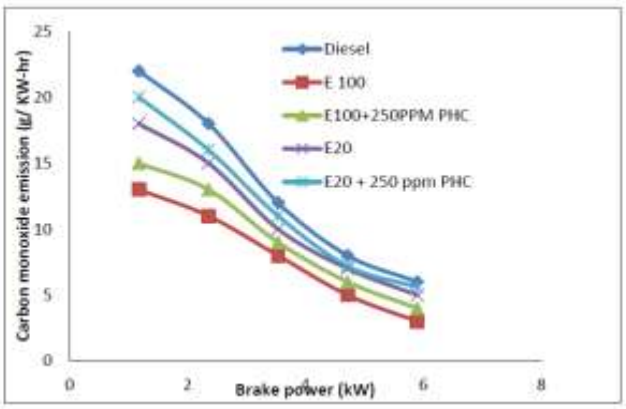

Fig. 3: CO Vs BP

The impact of antioxidant additives with eucalyptus fuel on release of HC is illustrated in fig. 4. The release of HC emission rises when antioxidants are added to the eucalyptus fuel, yet it is lesser than gasoline. Using three/ fourth load the release of HC increased while using E20and E100 fuels by 7.2% and 11.86%. During oxidation Peroxyl and hydrogen peroxide radicals are formed that is converted into hydroxyl radicals when it is absorbed in heat[14]. The higher level release of HC is because of lesser free radicals.

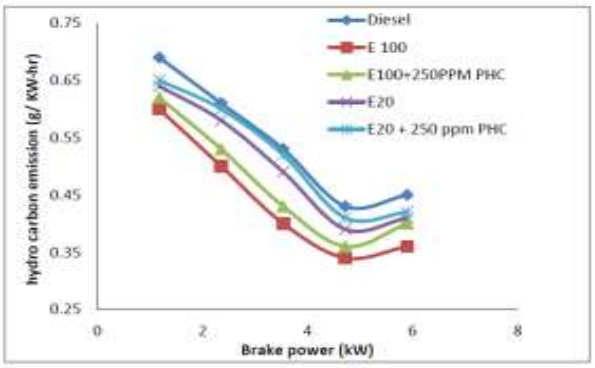

Fig. 4: HC Vs BP

B. The Brake Thermal Efficiency: Fig. 5 shows the deviation in BTE by applying varied loads using fuel blended with antioxidants. On applying full load, the engine effectiveness is less in contrast to the neat green fuel, but at part loads modification in BTE are alike, due to blending of

antioxidants. Using three/fourth load, PHC generated the brake thermal efficiency by using E20 BTE is 26.2%, by using E100 is 21.22%. No substantial change in BTE using E100 fuel by applying three/fourth load. Nevertheless, by applying Rated load 0.62% there is loss in the BTE. The lesser BTE is due to the combined effect of minimum heating value and high level of viscosity[15]. Lesser BTE might be because of slighter reduction in the cylinder pressure by adding antioxidants.

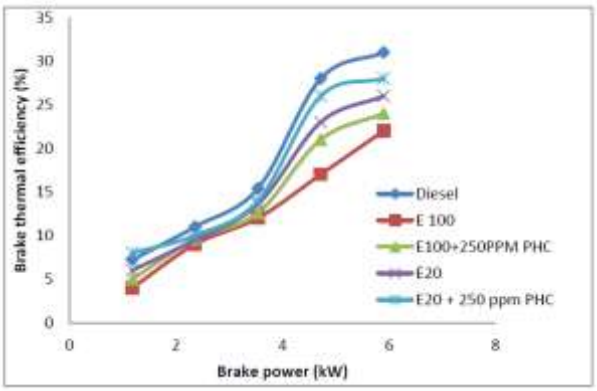

Fig. 5: BTE Vs BP

Conclusion

The objective of this empirical study had been due to the investigations on effect of antioxidant, the release of NO_X using Eucalyptus biofuel in DI diesel engine. Using antioxidants and blends of eucalyptus fuel causes lesser release of NOx. The PHC that resulted in high level release of NO_X in contrast to the DEA, TBHQ. By applying three/fourth load, the highest level release of NO_X using B20 fuel has been 18.21% and B + 250 ppm of Pyridoxine Hydro Chloride released lesser NOx.

The blend of antioxidant generated high release of CO and HC. The Pyridoxine Hydro Chloride additive of 250 ppm delivered high level release of CO to around 6.1% by using B20 fuel and 10.34% using B100 fuel. The release of HC increases to around 7.2% using E20+250 ppm of PHC and 11.8% by using E100+250 ppm of Pyridoxine Hydro Chloride fuel. Higher level release in CO, HC Maximum eminent while using E20s, because It have lower fuelborne oxygen in contrast to E100s. The brake thermal efficiency while using antioxidant is minor. Besides, slender reduction in BTE 0.62% was noted by applying full load on the blend with antioxidants.

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