Comparison of a thermal barrier coated engine using eucalyptus oil methyl esters and azadirachta indica methyl esters

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Abstract. Key features of a diesel engine such as the engine effectiveness, release of toxic gas and ignition are examined while using two methyl esters. One of the methyl ester is abstracted from Eucalyptus and the other from Azadirachta Indica. A trans-esterification process is applied on Eucalyptus and Azadirachta Indica oils. The green fuel is used as substitutes in Thermal barrier coating engine (TBC). The use of TBC increases by the temperature of combustion. Experiments carried by EUME, AIME in TBC Diesel engine. The result shows that, the BTE is reduced to the extent of 5.82% and 6.97% and an increase in BSFC to the extent of 11.68% and 12.61% using EUME and AIME in TBC engine in contrast to ordinary diesel propellant used engine. It has also been observed that the release of NOₓ increases in TBC engine also have higher-level release of CO, smoke and HC. The ignition features it has been discovered that the cylinder pressure of EUME and AIME in TBC engine are similar to that of diesel propellant at conventional engine.

1. Introduction

Since Usage of fuel is increasing day by day all over the world the resources are depleting. The scenario has created a situation to search for alternative fuels hence many researches has been carried out. Vegetable oils are imperishable and cause lesser release of toxic gas therefore they are considered as excellent resource of alternative fuel. Green fuel is one among the excellent alternative fuels [1]. Hence, now a day’s methodical attempts were undertaken by many researchers to utilize vegetable oils as propellant for diesel engines. Vegetables oils are sticky than diesel [2]. The trans-esterification reaction lessens the stickiness when triglycerides are altered into esters. Ester is considered as green fuel whereas glycerin is neglected [3]. 33.33% energy produced is given to water. The main focus of TBC engine is to lessen the temperature induced in water and transforming the energy into work [4]. Benefits of TBC concept are lesser release of hydrocarbons, carbon monoxide and smoke, fuel
To improve the engine's effectiveness, a conventional cooling system is used to lessen loss of engine energy. This will probably bring about 51% volume and 31% weight reduction in the combustion process. Few researches have indicated that high temperature combustion in lessens release of exhaust gases [5]. One of the demerits of insulating TBC engine is high level release of oxides of nitrogen and temperature increases to around 210–260 °C in contrast to identical diesel engine.

Experiments have been carried on using EUME, AIME and LHR coated engine and conventional engine. With The engine effectiveness the release of toxic gas and ignition have been analyzed and compared. Eucalyptus methyl ester [EUME], Azadirachta Indica methyl ester [AIME] has been used in TBC diesel engine and diesel engine.

2. Experimental Procedure

![Figure 1. Experimental Setup Layout.](image)

The basic model Kirloskar engine four stroke single cylinder direct diesel injected water-cooled engine has been used to perform experiments and analyze the characteristics in this research. Table 1 lists the key engine specifications. The diagrammatic representation of the investigational arrangement is shown in Fig 1. Test engine can be loaded using the eddy current dynamometer. The AVL dit-est 10^3 is used to quantifying the release of outgoing gas of the engine and release of particulate matter is measured using AVL di smoke 480. Eucalyptus methyl ester (EUME) is generated using a simple environment. Eucalyptus has been esterified using 3.55g of sodium hydroxide in addition of 210 milliliter of methyl alcohol. In eucalyptus oil the catalyst and alcohol are blended. Eucalyptus blend is kept that at 60 °C for one hour. Post transesterification mixture poured using a separating funnel, the green fuel and the glycerin are collected and the glycerin is shattered. The green fuel is eroded completely using unpolluted water. The green fuel is heated to a temperature of 110 °C in the form of vaporization [7]. Moreover, the similar method is used to generate Azadirachta Indica methyl ester (AIME) that is utilized as another green fuel for this investigative study. Table 2 shows few properties of Eucalyptus methyl ester, Azadirachta Indica methyl ester and diesel fuel.
### Table 1. The test engine specification.

| Parameters                       | Specifications                                                                 |
|----------------------------------|--------------------------------------------------------------------------------|
| Engine model                     | Kirloskar Tv SRII, single cylinder, natural articulated, DI Diesel engine       |
| Stroke length (mm)               | 110                                                                            |
| The Compression ratio            | 17.5:1                                                                         |
| Speed (rpm)                      | 1500 [constant]                                                               |
| Power (kw)                       | 5.2                                                                            |
| Dynamometer                      | EddyCurrent                                                                   |
| Injection pressure (bar)         | 210                                                                            |

### Table 2. Fuel Properties.

| Properties                  | Diesel | EUME | AIME |
|-----------------------------|--------|------|------|
| Calorific value (kJ/kg)     | 42560  | 41426| 41342|
| Kinematically viscosity      | 3.09   | 4.09 | 4.07 |
| Density (kg/m³)             | 830    | 881  | 892  |
| Carbon residue (%)           | 0      | 0.206| 0.382|
| Fire point (°C)              | 56     | 126  | 172  |
| Flash point (°C)             | 50     | 146  | 158  |

Diesel is supplied to the conventional engine. The insulation is composed of ZrO₂ (75%)-Al₂O₃ (25%) of 1cm thickness, ZrO₂ (50%)-Al₂O₃ (50%) of 1cm thickness and Al₂O₃ (100%) of 1cm thickness utilizing PCM and over ignoble of Nickel-Chromium bonding coat 0.15 mm thick. Testing procedure which is carried with diesel engine is used in TBC engine using EUME and AIME and the outcome of the tests are related with ordinary CI Engine.

## 3. Results and discussion

The empirical study presented in this journal aims to study the effectiveness of the engine, release of toxic gas, and ignition features of piston coated engine using EUME, AIME. The outcome of the tests of LHR engine are referred with that of the diesel engine.

### 3.1. The Brake Thermal Efficiency

Figure 2 illustrates the deviation in BTE verses BP using EUME, AIME at TBC engine and conventional engine using fuel (diesel). When the load increased the BTE rises at constant rate. It has been recorded that at 75% load the highest BTE reduces by 5.82% then 6.97% using EUME and AIME in TBC engine in contrast to that of the uncoated engine using diesel. The brake thermal efficiency lessens due to the problems in the fuel flow because of high level stickiness and density [8].
The BTE of methyl ester due to fuels high level stickiness and density the combustion engine also lessens for the eucalyptus and azadirachta indica oil. The optimum BTE of EUME, AIME at TBC engine is 27.34%, 26.93% for TBC engine in comparison with 30.06% of fuel in conventional engine on 74% load. Though using measured load, the BTE standards of EUME, AIME are 25.74%, 24.95% in TBC engine in contrast to 29.87% of diesel in conventional engine, that are 6.77%, 6.37% lesser to the fuel which is diesel in the diesel engine. At the outcome of the tests it has been observed that the BTE for AIME at TBC engine close to the fuel which is diesel in conventional engine.

![Figure 2. BTE Verses BP.](image)

3.2. The Brake Specific Fuel Consumption

![Figure 3. BS Fuel Consumption Vs BP.](image)

Deviation in BSFC verses BP using EUME, AIME at TBC engine and fuel which is diesel in conventional engine were diagrammatically represented at Figure 3. The BSFC reduces on increasing the load. The SFC for two methyl esters at TBC engine is greater in contrast to the fuel (diesel) in conventional engine by applying different loads [9] because of dissimilarities in boiling value and mass between EUME, AIME and conventional diesel. From measured load BSFC of EUME, AIME is 0.35, 0.30 kg/kWh at TBC engine in contrast to 0.27 kg/kWh of diesel in conventional engine. There are 11.68% and 12.61% of rise in specific fuel consumption using EUME, AIME at TBC engine in
contrast to the fuel (diesel) at CI engine. At the analysis the SFC of AIME at TBC engine was closer to the diesel in conventional engine.

3.3. Brake Specific Energy Consumption

Figure 4. BSEC Verses Brake power.

Figure. 4 shows a diagrammatic representation of deviation in the BSEC Verses BP using EUME, AIME at TBC engine and fuel (diesel) in conventional engine. BSEC using methyl esters in Eucalyptus and Azadirachta Indica shows higher level in contrast to using the fuel (diesel) in conventional engine to the level of 75% load. This is because of the dissimilarities in the density, heating values amongst EUME, AIME and fuel(diesel). From measured BSEC of EUME, AIME at 13.95 MJ/kWh, 13.07 MJ/kWh at TBC engine in comparison with 12.62 MJ/kWh fuel (diesel) in conventional engine. From the outcome of the tests its shown that the BSEC of AIME used at TBC engine as well as compatible in fuel (diesel) at conventional engine.

3.4. Exhaust Gas Temperature

Figure 5. EGT Verses Brake power.

A diagrammatic representation to show the similarities in release of exhaust gas on using BP for EUME, AIME at TBC engine in addition to diesel at conventional engine is shown at Figure 5. The exhaust valve gas temperature is greater in TBC engine in contrast to that the uncoated CI engine. from greater loads, the outgoing valve temperature of gas of EUME, AIME at TBC engine stays still
more in contrast to fuel at conventional engine. The highest stickiness and poor explosiveness of the fuel results to a higher level of foremost diffusing combustion stage than that of the fuel. Moreover, the delay in the ignition of methyl esters causes slower combustion that leads to high level of exhaust gas temperature [10]. In measured load is optimum outgoing valve temperatures of gas using EUME, AIME at TBC engine has been 490.22 LC and 496.55 LC in contrast to 448.14 LC while using diesel in conventional engine and which shows 9.14%, 10.62% ≥ diesel in engine.

3.5. Unburned Hydrocarbon Emission

![Figure 6. HC Verses Brake power.](image)

A diagrammatic representation in the deviation of release without burned hydrocarbons with BP using EUME, AIME in TBC engine & fuel at conventional engine which is shown at Figure 6. The prime cause is the production of HC due to fractional combustion [11]. Not completely burned HC released while using EUME and AIME in TBC engine is greater in contrast to diesel in basic model engine. The impact of high-level fuel stickiness, thickness of the fuel spray quality results in increase in the release of hydro carbon with methyl esters. The higher stickiness of EUME and AIME results in deprived ignition because of inadequate atomization. Additional cause in higher level release of hydrocarbon while using Eucalyptus and Azadirachta Indica methyl esters could be because of the propellants bodily possessions such as viscidity and density, this has better impact on release of HC in contrast to the fuel biochemical properties [12]. At the highest load the without burned hydrocarbon using EUME and AIME in TBC engine is 89.76 ppm and 88.21 ppm in contrast to 85.92 ppm while using fuel (diesel) in conventional engine, the change is 3.72% and 2.59% are greater in contrast to using diesel in uncoated engine.

3.6. Carbon Monoxide Emission

The above figure shows the deviation in BP with CO using EUME, AIME at TBC CI Engine with fuel (diesel) at uncoated engine. The CO using EUME in addition AIME at TBC engines are greater in contrast to using diesel in uncoated engine. It has been discovered that, about 50% of the shipment the carbon monoxide come near these methyl esters in Eucalyptus and Azadirachta Indica in TBC engines fit similar with fuel (diesel) at conventional engine. From measured load the optimum release of carbon monoxide from TBC engine using EUME, AIME are 0.32%, 0.41% in contrast to 0.25% of diesel in conventional engine, which are 25.87%, 38.49% ≥ the fuel at conventional engine. Its purpose might be due, to the impact of fuel viscidity [12]. The tendencies disclose that the combustion proficiency reduces by using methyl esters in Eucalyptus and Azadirachta Indica while operating TBC engine.
Deviation in release of brake power with oxides of nitrogen using EUME, AIME at TBC engine and fuel (diesel) in conventional engine is depicted in Figure 8. Main reason for the creation of the oxides of nitrogen because of the oxidation of impressive nitrogen [13]. The responses, that form NOX is due to oxygen and high temperatures. Release of NOX on using EUME and AIME in TBC engine is high in contrast to using diesel in conventional engine. It is high because of presence of oxygen contented in the EUME in addition to AIME, as per the oxygen the availability in the fuels afford additional oxygen to form oxides of nitrogen. It has as well been observed that the release of NOX rises on rising BP while using completely the trial diesel. From optimum load, the NOX’s stages of using EUME, AIME at TBC engine are 646.25 ppm, 644.02 ppm in contrast to 612.15 ppm using diesel in conventional engine. The noted level of 20.59% and 10.46% are higher in contrast to that of diesel in uncoated engine. Release of NOX from TBC engine is more in contrast to non-TBC diesel engine because of higher combustion temperature.

3.7. Oxides of Nitrogen Emission

Deviation in smoke opacity through BP using EUME, AIME at TBC engine and diesel in conventional engine is depicted in Figure 9. In TBC engine the release of smoke using the EUME and AIME are greater in contrast to using diesel in uncoated engine. High percentage in release of smoke is because
of more stickiness and insufficient atomization of the fuel [14]. The smoke stages at highest load using EUME, AIME at TBC engine are 90.14%, 94.18% but smoke level is only 91.8% which using diesel in uncoated engine. The smoke level using EUME, AIME at TBC engine are 2.19%, 4.22% more in contrast to using diesel in uncoated engine.

![Figure 9. Smoke Opacity Versus Brake power.](image)

3.9. The Cylinder Pressure verses Crank Angle
In a compression ignition engine, cylinder pressure provides info around the incineration efficiency. The pressure inside the cylinder is mostly reliant on fuel singed portion at the primary incineration point [15]. Average load of 100 cycle at 75% from this pressure inside the cylinder is taken with crank angle value. The deviation in crank angle with cylinder pressure using EUME, AIME in TBC engine and fuel at conventional engine can be known by Fig 10. The outcome shows the higher pressure of together the methyl esters in TBC the engine is lesser in contrast to that of diesel in conventional engine. At 75% load, peak pressure reaches up to the optimum level of 63.62 bar, 62.11 bar and 67.57 bar using EUME, AIME in TBC engine and fuel (diesel) in conventional engine. This is because of very high stickiness of oil and low inflammability of EUME and AIME resulting in poor atomization.

![Figure 10. The Cylinder pressure Versus CA.](image)

3.10. Heat Release Rate with Crank angle
Deviation in crank angle with HRR using EUME, AIME at TBC engine and fuel (diesel) in conventional engine is illustrated in Fig 11. The heat release using EUME and AIME in TBC engine is less in contrast to that of diesel in conventional engine because of lesser calorific value of these methyl
esters. The premixed combustion stage using EUME, AIME at TBC is shorter in contrast to that of fuel (diesel) in conventional engine that results in lesser heat release rate. This is the purpose for lesser BTE while using methyl esters of Eucalyptus in additional to Azadirachta Indica at TBC engine.

4. Conclusion

The current empirical study has made use of coated and conventional CI engine using EUME, AIME and diesel. The TBC engine using EUME, AIME has been analyzed and contrasted through that of diesel at conventional engine. Using Azadirachta Indica methyl ester TBC engine enhances the performance of the engine in contrast to using Eucalyptus methyl ester nonetheless comparing diesel in conventional engine, the engines effectiveness of TBC engine using methyl esters is lesser.

The brake thermal efficiency on using EUME, AIME at TBC engine is ≤ that of diesel in conventional engine by 5.828%, 6.97%. from measured load, the BSF ingesting values using EUME and AIME in TBC engine is high in contrast to that of diesel in ordinary engine by 11.68% and 12.61%.

The exhaust gas temperatures on using EUME, AIME at TBC engine are high in contrast to that of diesel in conventional engine. At higher load, the release without burned hydrocarbon emissions using EUME, AIME at TBC engine is 89.76 ppm and 88.21 ppm in contrast to 85.92 ppm using diesel in conventional engine, that are 3.72% and 2.59% high than that of diesel at conventional engine. In additional to that the release of CO using EUME, AIME at TBC engine is higher by 25.87% and 38.49% in contrast to that of diesel in conventional engine.

The oxides of nitrogen level using EUME, AIME at TBC engine are 20.59% and 10.46% that are high in contrast to that of diesel fuel at conventional engine. The smoke usage levels at peak load using EUME and AIME in TBC engine are 90.14%, 94.18%, but smoke level is 91.8% using diesel at conventional engine. The smoke level using EUME, AIME at TBC engine is 2.19% and 4.22% that is high in contrast to that of using diesel in conventional engine. At 75% load, the optimum pressure reaches up to the maximum of 63.62 bar, 62.11 bar and 67.57 bar using EUME, AIME at TBC engine and diesel at conventional engine. low heat release rates have been noted with methyl esters using Eucalyptus and Azadirachta Indicain TBC engine during premixed combustion in contrast to diesel at conventional engine.

This comparison points out an opportunity of using the methyl esters at TBC engine. The engines effectiveness, releases of toxic gas and combustion analysis indicates that is suitable to use Eucalyptus and Azadirachta Indicamethyl esters as different fuels at TBC engine.
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