Effect of Kerosene and Methanol Blending with *Pongamia Pinnata* Biodiesel on Diesel Engine Performance and Emission Characteristics

R. Sathish Kumar¹*, R. Rajaraman², V. Nadanakumar¹, R. Christu Paul¹, S. Ganesan³ and Ravishankar Sathyamurthy⁴

¹Department of Automobile Engineering, Hindustan Institute of Technology and Science, Padur, 603 103, Tamilnadu, India.
²Department of Mechanical Engineering, SRM Institute of Science and Technology, Vadapalani Campus, Chennai-600026, Tamilnadu, India.
³Department of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai-600119, Tamilnadu, India.
⁴Department of Mechanical Engineering, KPR Institute of Engineering and Technology, Coimbatore, 641407, India.

*E-mail: sathish.rajamanickam@gmail.com

Abstract. In this present work, a novel blend of biodiesel is used to investigate the performance and emission characteristics of an unmodified diesel engine. *Pongamia Pinnata* is used to extract oil and transesterification process is done to reduce its viscosity. Different fuel blends were prepared using biodiesel which includes D20 blend with diesel, K20 blend with Kerosene and M20 blend with Methanol, the fuel prepared were used in the engine to analyse the performance and emission characteristics of the engine. The results were compared with the standard fuel mineral diesel. A considerable increase in brake thermal efficiency is observed for D20 blend. The blend K20 shows considerable improvement in the performance as well as reduction in the emission when compared to all other fuels.

Keywords: *Pongamia pinnata*, Kerosene, Methanol, Emission, Diesel engine.

1. Introduction

Research on the use of biodiesel is vital in recent times because of depletion and environment effects of conventional fuels which are readily available. Still many researches are on way based on renewable and alternate fuels for IC engines. Diesel engines have better thermal performance, low emission in terms of HC and CO, but NOₓ are emitted in large concentration. The formation of NOₓ is mainly due to rich mixture, temperature, high sulphur content. So the use of blends in fuel is necessary

* R Sathish Kumar, Department of Automobile Engineering, Hindustan Institute of Technology and Science, Padur, 603 103, Tamilnadu, India. (sathish.rajamanickam@gmail.com)
to meet the required emission norms. So the use of biodiesel and various blends are important to meet both the depletion and emission.

Uses of biodiesel are increasing in recent times to overcome the above problem. Biodiesel oil is extracted from number of ways such as coconut, palm, vegetables, cooking oil, sunflower, animal fat, rapeseed and canola. Biodiesel are non-toxic, apart from toxicity biodiesel are sulphur free, renewable and contains large amount of oxygen. Biodiesel normally used are of non-consumable oil by humans. The biodiesel use in this investigation is Pongamia Pinnata. Pongamia Pinnata is a tree falling into Pea Family, which is mostly available in China, Japan, Malaysia, Australia, Indian subcontinent and Pacific islands. This oil is mainly used as lamp oil, soap making and for lubrication purposes also. Zhi-Hui Zhang (2015) evaluated the use of higher alcohol such as n-butanol and n-pentanol with biodiesel, use of both alcohol result an increase in thermal efficiency and specific fuel consumption and reduction in elemental carbon, NOₓ, and particulate matter. Out of these alcohols butanol was superior to pentanol.

Harish Venu (2016) used diethyl ether along with alcohol-biodiesel-diesel blend. The combination includes 20% methanol and 20% ethanol along with 40% biodiesel and 40% diesel. The biodiesel used is Jatropha oil. Use of diethyl ether results increase in Brake Specific Fuel Consumption, cylinder pressure, HC, CO and CO₂, but reduction in NOₓ, Smoke and Particulate matter. J Zaglinskis (2015) deals with the comparison of biodiesel-diesel with methanol additives. In this experiment 10% of methanol is added to the blend. Zaglinskis (2015) reported that there was an increase of 13% for Brake Specific Fuel Consumption, 2.5% for Brake Thermal efficiency, 1.2% for Carbon dioxide emission whereas an average reduction of 10%, 13% and 45% for NOₓ, CO and Soot respectively. HC emission was ranging from -8% to +18% for various loads.

Nadir Yilmaz (2012) has done an analysis based on Biodiesel-methanol and Biodiesel-ethanol blends. Here 2% of castor was added to overcome the disadvantages of above alcohols such as low lubrication, difficult vapourisation and high auto-ignition temperature. Result found out that Brake Specific Fuel Consumption (BSFC) was more for Biodiesel-methanol that Biodiesel-ethanol, but BSFC of both are higher than pure diesel. Biodiesel-alcohol shows an increment in CO and HC but similar at full load as pure diesel, but shows a reduction in NOₓ, smoke and soot. In another paper Nadir Yilmaz (2012) has done an analysis between biodiesel-ethanol-diesel and biodiesel-methanol-diesel blends. Yilmaz (2012) observed that biodiesel-methanol-diesel shows an increase of BSFC and NO than biodiesel-ethanol-diesel. Whereas biodiesel-methanol-diesel shows a reduction of CO, NOₓ, and exhaust temperature.

Murari Mohan Roy (2014) has done an experiment using canola oil and kerosene blend along methanol and sodium hydroxide. Roy reported that an increase of 10.5% in Brake Specific Fuel Consumption with pure kerosene compared to pure diesel. Efficiency and CO increases as kerosene concentration increases in Kerosene-biodiesel blend. Whereas NO and NO₂ decreases as kerosene concentration increases in Kerosene-biodiesel blend. K.R Patil (2014) has done an investigation of Diethyl ether-kerosene-diesel blend. K.R Patil (2014) has experimentally achieved reduction in Brake Specific Fuel Consumption, NOₓ and CO₂ but an increase in HC and peak pressure than pure diesel. Longfei Chen (2017) has done a study of kerosene-pentanol blend. Pentanol is mainly used to increase viscosity and oxygen content. Longfei Chen (2017) reported that heat release were similar for pure diesel, pure kerosene and kerosene (80%)-pentanol (20%) blend. Kerosene-pentanol blend shows a reduction in soot, CO, HC emission and thermal efficiency.

In this study in order to reduce the NOₓ emission the use of kerosene and methanol is used as additive for increasing the performance of blend in Pongamia Pinnata are included in this project. The use of alcohol blends with diesel result in formation of mixture, which has an attraction towards water molecules which result in malfunction of fuel injector. From various alcohol methanol is selected because of latent heat properties and improved volatile. This paper also deals with the comparison of performance between methanol and kerosene. This study also includes the comparison between kerosene and methanol effects with pure diesel and various diesel blends with kerosene and methanol.
2. Materials and Methodology

2.1. Test Fuels

Pongamia pinnata which is used as a source for preparing the biodiesel, is a non-edible plant grown in China, Japan, Malaysia, Australia, Indian subcontinent and Pacific islands. The seeds of the plant are collected, dried and crushed in a cold pressed rotary oil expeller. As the viscosity of the neat oil is higher, the same can’t be used in the engine. It may create some troubles like clogging of oil filters, choking of fuel injectors etc., Hence the viscosity has to be reduced. There are several methods available to reduce the viscosity of the oil, out of which the transesterification process is found to be easier and efficient. So in this work transesterification is done to reduce the viscosity of the Pongamia Pinnata oil. Transesterification was performed by heating the oil and methyl alcohol (10% V/V) upto 50°C using KOH (1% w/w) as a catalyst. The above mixture were stirred at 600 rpm for 90 min. The mixture is then transferred to a separating flask and maintained for 24 hours. The fatty acid methyl ester and the glycerol were found in two different layers and the glycerol is separated. The collected FAME is washed with distilled water and heated for the removal of water and residual methanol. The yield of FAME is found to be 96.4 %. The bio diesel produced is blended with diesel, kerosene and methanol as shown in the table 1.

Table 1. Description of Fuel Blend.

| Sl.No. | Blend | Description               |
|-------|-------|---------------------------|
| 1     | D100  | 100% pure diesel          |
| 2     | D20   | 20% diesel + 80% biodiesel|
| 3     | K20   | 20% kerosene + 80% biodiesel|
| 4     | M20   | 20% methanol + 80% biodiesel|

The blends were prepared on volume basis and continuously stirred for 30 min with the magnetic stirrer for achieving stable property values. The properties of test fuels are showed in Table 2.

Table 2. Properties of Test Fuels.

| Sl.No. | Blend | Calorific Value (MJ/kg) | Density (g/cc) | Kinematic viscosity (mm²/s) |
|--------|-------|-------------------------|----------------|---------------------------|
| 1      | D100  | 48.700                  | 0.875          | 2.16                      |
| 2      | B100  | 44.800                  | 0.950          | 7.08                      |
| 3      | M20   | 35.09                   | 0.870          | 3.13                      |
| 4      | K20   | 34.28                   | 0.890          | 4.36                      |
| 5      | D20   | 35.59                   | 0.886          | 4.89                      |

2.2. Experimental procedure

The setup includes a single cylinder four-stroke water cooled, constant speed (1500 rpm) direct injection, compression ignition engine. A rheostat (salt-water) is equipped for applying the required load. A gas analyser, model AUTO 5-1 by M/s Kane International Ltd., is coupled to engine for measuring the emission parameters. The description of analyser and test engine is given in the Table 3 and Table 4 respectively. The quantity of the fuel consumed is recorded manually. Time taken for consuming 20 cc of the fuel is observed by stopwatch. For every load conditions three trials are done and the average of them is used for calculations.

The schematic diagram of the experimental setup is shown in Figure 1. The experiments are done by running the engine at different load conditions from zero to full load. After applying each load the engine is allowed to stabilize before taking the readings. The readings from the Ammeter and Voltmeter are recorded. The emission measurement are recorded from the gas analyser apparatus.
Table 3. Gas Analyser Specification.

| Parameter | Range       | Detection principle |
|-----------|-------------|---------------------|
| CO        | 0-20%       | NDIR                |
| UBHC      | 0-10,000 ppm| NDIR                |
| NO        | 0-5000 ppm  | Electro chemical    |
| CO₂       | 0-20%       | NDIR                |
| NOₓ       | 0-5000 ppm  | Electro chemical    |

Table 4. Specification of CI Engine.

| Description                  | Value          |
|------------------------------|----------------|
| Manufacturer Name            | Kirloskar      |
| Brake Power                  | 3.68 kW        |
| Rated Speed                  | 1500 rpm       |
| Stroke Length                | 110 mm         |
| Diameter of cylinder         | 87.5 mm        |
| Compression Ratio            | 16.5:1         |
| Efficiency of generator      | 82%            |
| Rated voltage on generator   | 220 V          |

Figure 1. Schematic View of Experimental Setup.

3. Results and Discussions

3.1. Variation of BSFC

The variation of BSFC (Brake Specific Fuel Consumption) with load at constant speed of 1500 rpm is shown in figure 2. From the figure it is observed that M20 has higher BSFC compared to all test fuels. As engine load increases the BSFC decreases for all test fuel. The BSFC is higher for all other test fuels that diesel; this is due to the reason that lower Calorific value for other fuels than diesel. The BSFC of D20 is closely approaching that of D100, which is due to greater influence of viscosity on BSFC. The BSFC of K20 at 40% to 60% is lower than any other test fuels. This is due to better flow characteristics of the fuel at elevated temperature and increased efficiency of engine.
3.2. Brake Thermal Efficiency

The variation of BTE (Brake Thermal Efficiency) with load at constant speed of 1500 rpm is shown in figure 3. The thermal efficiency all other test fuels are lower than that of diesel, this is due to presence biodiesel in the blends which has reduced calorific value and increased viscosity inhibiting poor atomization of fuel. The thermal efficiency of K20 is highest for all other fuels. This is due to better combustion other blends. The thermal efficiency of D20 approaches K20.

3.3. Exhaust gas temperature

Figure 4 shows the variation of exhaust gas temperature with engine load. It is observed that exhaust gas temperature is lower for all other test fuels than diesel up to 40% engine load and reduces
thereafter. This is due better combustion of test fuels because of additional oxygen content provided by biodiesel. It is observed that exhaust gas temperature increases as engine load increases. For all fuels, as load increases the amount of fuel injected must be increased in order to keep up the required power which in turn increases heat release and exhaust gas temperature. Out of all test fuel D20 blend exhibits highest exhaust gas temperature. But on average K20 blend has least exhaust temperature than diesel and any other test fuels.

![Load Vs Exhaust Gas Temperature](image)

**Figure 4.** Variation of Exhaust gas temperature with respect to load.

### 3.4. CO emission

The variation of CO emission for the test fuel with respect to engine load is shown in figure 5. The CO emitted by test fuels is higher than that of diesel at higher loads. This due to the reason that short time is available for combustion so incomplete or partially burning of fuels takes place. In constant speed engines more amount of fuel are required to compensate for increasing load but the time required for burning the fuel is shorter leading to incomplete combustion. On average M20 and pure diesel emits almost same amount of CO. it is observed that D20 emits larger amount of CO.

### 3.5. CO₂ emission

Figure 6 shows the variation of CO₂ with respect to engine load. It is observed that M20 and K20 emits lower amount of CO₂ than diesel, which is due to presence of low carbon amount in biodiesel. The CO₂ emission increases with the increasing engine load for all blends. The average CO₂ emission of D20 is similar to pure diesel due to similar combustion nature. Out these test fuels on average K20 exhibits lower amount of CO₂.

### 3.6. HC emission

The HC emission variation of the test fuels with respect to engine load is given in figure 7. The HC emission increases with increase in engine load. It is observed that D20 blend emits the highest amount of HC. This due to the reason that the addition of biodiesel which result in the higher viscosity and poor mixing. The addition of kerosene and methanol reduces the average HC emission than pure diesel, which is due to low carbon content in biodiesel.
Figure 5. Variation of CO with respect to engine load.

Figure 6. Variation of CO₂ with respect to engine load.

3.7. NOₓ emission
Figure 8 depicts the variation of NOₓ emission with respect to engine load. It is observed that NOₓ emission increases with increase in engine load. On average all test fuels emits higher amount of NOₓ than pure diesel, also percentage increase of NOₓ emission is more at higher load. This is due the reason that there is an increase in combustion temperature due to addition of biodiesel. Also decrease in cetane number by addition of methanol which leads to increase in ignition delay and rapid heat release at higher loads.
4. Conclusion
The effects of various blends such as addition of biodiesel to diesel, addition of kerosene and methanol to biodiesel have been investigated in this work. Addition of kerosene and methanol has an appreciable improvement in emission parameters. The main conclusion of this investigation is as follows:

- There is an increase of 3.2% in thermal efficiency and decrease of 13.41% CO for K20 blend also there is a reduction of 2% in Brake Specific fuel consumption for K20 with 5.8% increase in NOx emission in comparison with diesel at medium engine loading condition. But there is an increase of 4.25%, 23.8%, 6.2%, 3.2% and 16.7% in exhaust gas temperature, CO\textsubscript{2}, HC, NO\textsubscript{x} and NO respectively for K20 than pure diesel at full load condition.
• The K20 blend can be superior substitute for pure diesel, for an existing engine with improved engine performance and better exhaust emission as K20 blend only shows a weakness in terms of NOx emission.

5. References
[1] Zhi-Hui Zhang and Rajasekhar Balasubramanian. Investigation of Particulate Emission Characteristics of a Diesel Engine Fueled with Higher Alcohols/Biodiesel Blends. Applied Energy. 2016;163:71-80.
[2] Haresh Venu and Venkataramanan Madhavan. Influence of Diethyl Ether (DEE) Addition in Ethanol-Biodiesel-Diesel (EBD) and Methanol-Biodiesel-Diesel (MBD) Blends in a Diesel Engine. Fuel, 2016;189:377-390.
[3] Zaglinskis, J., K. Lukacs and A. Bereczky. Comparison of Properties of a Compression Ignition Engine Operating on Diesel-Biodiesel Blend with Methanol Additive. Fuel. 2015;170:245-253.
[4] Nadir Yilmaz and Tomas M. Sanchez. Analysis of Operating a Diesel Engine on Biodiesel-Ethanol and Biodiesel-Methanol Blends. Energy. 2012;46:126-129.
[5] Nadir Yilmaz. Comparative Analysis of Biodiesel-Ethanol-Diesel and Biodiesel-Methanol-Diesel Blends in a Diesel Engine. Energy 2012;40:210-213.
[6] Murari Mohon Roy, Wilson Wang and Majed Alawi. Performance and Emission of a Diesel Engine Fueled by Biodiesel-Diesel, Biodiesel-Diesel-Additive and Kerosene-Biodiesel Blends. Energy Conversion and Management. 2014;84:164-173.
[7] Patil, K.R. and S.S. Thipse. Experimental Investigation of CI Engine Combustion, Performance and Emission in DEE-Kerosene-Diesel Blends of High DEE Concentration. Energy Conversion and Management. 2015;89:396-408.
[8] Longfei Chen, Shirun Ding, Haoye Liu, Yiji Lu, Yanfei Li and Anthony Paul Roskilly. Comparative Study of Combustion and Emission of Kerosene (RP-3), Kerosene-Pentanol Blends and Diesel in a Compression Ignition Engine. Applied Energy. 2017;203:91-100.
[9] Hasan Bayindir, Mehmet Zerrakki Isik, Zeki Argunhan, Halit Lutfu Yucel and Huseyin Aydin. Combustion, Performance and Emission of a Diesel Power Generator Fueled with Biodiesel-Kerosene and Biodiesel-Kerosene-Diesel Blends. Energy 2017;123:241-251.
[10] Cheolsoo Lim, Jongtae Lee, Jihyung Hong, Changkeun Song, Jinseok Han and Jun-Seok Cha. Evaluation of Regulated and Unregulated Emissions from Diesel Powered Vehicle Fueled with Diesel/Biodiesel in Korea. Energy. 2014;77:533-541.
[11] Sathish Kumar, R. and K. Suresh Kumar. Effect of methanol blending with Pongamia pinnata biodiesel and diesel blends on engine performance and exhaust emission characteristics of an unmodified compression ignition engine. International Journal of Ambient Energy. 2015;36(2):70-75.
[12] Nadanakumar, V., A.A. Arivalagar, N. Alagumurthi. Studies on production and optimization of silkworm biodiesel. Journal of Chemical and Pharmaceutical Sciences. 2016; 9(4):3063-3069.