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Emission Analysis on Cashew Nut Biofuel in Compression Ignition Engine

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Abstract

In this present work, the impact of blending n-Pentanol, a next generation bio fuel with cashew nut shell biodiesel (CNSL) on the performance of a diesel engine are examined. Tests were performed on a constant speed compression ignition engine using n-Pentanol / cashew nut shell biodiesel blends. N-Pentanol was added to cashew nut shell biodiesel by 5 and 10% by volume. Performance parameters namely break thermal efficiency (BTE), Brake specific fuel consumption (BSFC) and Exhaust gas temperature (EGT) were analyzed in this work. It was experimentally found that by adding n-Pentanol to neat cashew nut shell biodiesel, significant reduction in viscosity was observed. In addition, break thermal efficiency was increased by 0.8 % due to improved atomization of the blends. Further, brake specific fuel and exhaust gas temperature was further reduced due to lower viscosity and improved combustion rate with addition of n-Pentanol to cashew nut shell biodiesel. Emission parameters such as Hydro carbon (HC), Carbon monoxide (CO), Nitrogen oxides (NOX) and Smoke emissions were examined at different load conditions. Addition of n-Pentanol as additive improves the rate of combustion, mixing and vaporization of the blends with air and reduces the emissions associated with it. Components were observed during the trail.

Keywords: n-Pentanol, cashew nut shell biodiesel blends, rate of combustion, vaporization.

1. Introduction

Biodiesel is a renewable alternative fuel for non-renewable energy resource like diesel, petroleum, natural gas and coal which comes under conventional fuel category [1]. This modern biodiesel is prepared from vegetable oil or animal fat which are chemically reacted with the alcohol content to produce long chain alkyl ester [2]. We are in the century were the whole world is facing energy crisis as the fossil fuels are getting exhausted day by day as the need for energy increases, so scientist have put forward many theories and researches to replace the fossil fuel with most suitable renewable energy resource[3]. As a result the biodiesel was the most appropriate renewable fuel which replaces the conventional fuel [4]. Biodiesel are preferably adopted because it conforms the stringent emission regulation and has the minimal sulphur content, high cetane number and higher lubricity [5, 6]. Based on several researches, the researchers have found that the engine fuelled with biodiesel has the propensity to effuse less carbon monoxide, hydrocarbon, and particulate matter when compared with diesel powered engine [9]. At the same time the biodiesel has many drawbacks like high emission rate of oxides of nitrogen which is usually known as NOX and the cost of producing biodiesel [11]. It is more expensive to produce biodiesel because it involves several chemical processes as vegetable oil or animal fat cannot be used in IC engine without processing [7]. The suitability of biodiesel is very less at low temperature, than petro diesel because the cloud point of the biodiesel are very low so it has the ability to form wax crystals which resembles like gel and it is difficult to be pumped [8]. Fuel additives play a vital role in biodiesel as it has the ability to alter the fuel properties and makes it suitable for use in diesel engines [10]. There is no need for the modification of the engine to use biodiesel as the fuel additives change the molecular structure of the fuel and enhance the chemical reaction and the engine attains a better performance rate [12]. Fuel additives are used to neutralize the starting problem faced by the diesel engines during the cold climatic weather [13]. Energy is very important for life quality and social development of people as well as economic growth [14]. Fossil fuels have been an important conventional energy source for years. Energy demand around the world is increasing at a faster rate as a result of ongoing trends in industrialization and modernization [15]. Most of the developing countries import fossil fuels for satisfying their energy demand. Consequently, these countries have to spend their export income to buy petroleum products. The climate changes occurring due to increased Carbon Dioxide (CO2) emissions and global warming, increasing air pollution and depletion of fossil fuels are the major problems in the present century [16]. The present researchers have been focused on the bio fuels as environment friendly energy source to reduce dependence on fossil fuels and to reduce air pollution [17]. The bio fuels can play an important role towards the transition to a lower carbon economy and also combine the benefits of low greenhouse emissions with the reduction of oil import [18]. The role bio fuels can play within these economies becomes clearer when their relatively developed agricultural sector is taken into account [19]. Bio ethanol, biodiesel and to a lesser extent pure vegetable oils are recently considered as most promising bio fuels [20]. Since 19th century, ethanol has been used as a fuel for diesel engines. Ethanol is a low cost oxygenated compound with high oxygen content (34.8%). Ethanol is an alcohol most often chosen because of the ease of production, can be obtained from various kinds of biomass such as maize, sugarcane, sugar beet, corn, cassava, red seaweed etc., relatively low-cost and low toxicity [21]. Diesel-ethanol blends are a more viable alternative and require little or no change in diesel engines. The use of diesel-ethanol blends can significantly reduce the emission of toxic gases and particulate matters when compared to pure diesel [22]. Ozer Can et al investigated the effects of ethanol addition to Diesel on the performance and emissions of a four stroke cycle, four cylinder, and turbocharged indirect injection diesel engine with different fuel injection pressures at full load. They showed that the ethanol addition reduces Carbon monoxide (CO), soot and Sulphur Dioxide (SO2) emissions, but increases Oxides of nitrogen (NOx) emissions [23]. They showed that the thermal efficiencies of the engine fuelled by the blends were comparable with that fuelled by diesel, with some increase of fuel consumption. They also found reduced smoke emissions, CO emissions above half loads, and increased HC emissions with the blends comparing with the diesel fuel [24].the CO and HC emission concentration in the engine exhaust decreased while the NO_x concentration increased [25].the concentration of CO_2 was found to be slightly increased and NO_x was reduced when ethanol blends were used [26].

2. PRODUCTION OF BIO DIESEL AND MATERIAL:

2.1 Cashew Nut Shell Plant

Cashew nut shell plant grows well in marginal or poor soil and it is drought resistant perennial. It has a life span of 50 years till then it produces seeds for the production of cashew nut shell oil. The seeds of cashew nut shell plant have 25-30% of oil content and the oil can be used as fuel without being concentrated. The by-products produced are used as organic fertilizers, as the seeds naturally contain insecticide. It has the ability to propagate well in scorched or semi scorched condition shown in fig1.

<Insert Figure 1>

It grows up to 3-5 meters in height and petiole length ranges between 6-23 mm.The fruits are usually produced in the winter season were the shrubs are leafless. The fruit takes two to four month to turn into yellow from green colour during this period the seed gets mature enough to produce cashew nut shell oil. It occurs mainly at lower altitudes 0-500 m in areas with mean annual temperatures between 20°C-28°C. It requires an average annual rainfall of 300-1000 mm.

2.2 Cashew Nut Shell Oil

The primary sources for cashew nut shell oil are the seeds of cashew nut shell plant which contains 25-30% of oil content in it. The chemical element Cursin present in the seed are highly toxic and therefore it is not suitable for human consumption. The vital objective of cashew nut shell cultivation is to extract cashew nut shell oil which can be trans-esterified for the production of biodiesel. The saponification value of the oil is high hence in some countries it is used for making soap and also as an illuminant in lamps as it burns without emitting smoke. It is important to point out that the cashew nut shell curcus oil can replace the conventional diesel oil since it has good chemical and performance characteristics when compared with the conventional diesel. The chemical composition of Cashew nut shell oil is as shown in table1.

<Insert table 1>

2.3 Transesterification Process

The seeds of the cashew nut shell plant are processed in the ram or screw presses to extract the oil content from it by chemically or enzymatically using a novel technique called aqueous enzymatic oil extraction. The oil is then reacted with the alcohol and a suitable catalyst to produce biodiesel this process is known as transesterification. The carbon atoms per molecule present in the crude cashew nut shell oil is higher in number which gives rise to higher viscosity and lower cetane number to it. Since the viscosity is high and the cetane number is low, improper atomization and incomplete combustion takes place in the engine. To increase the combustion characteristics, the crude cashew nut shell oil must be converted into cashew nut shell biodiesel by transesterification process [27].

Transesterification is the process of converting a triglyceride and removing the glycerine from the cashew nut shell oil and forming an alcohol ester. Cashew nut shell oil is heated and stirred continuously and simultaneously the alcohol and NaOH which acts as a catalyst is added to it. After heating the oil for certain amount of time the mixture is then allowed to
Settle under gravity. Cashew nut shell biodiesel is formed in the top layer and the impurities along with the glycerine are settled down in the bottom layer. The biodiesel is then separated from the impurities and used in the IC engine shown in fig 2.

Triglycerides (**1**) are reacted with an alcohol such as methanol (**2**) to give ethyl esters of fatty acids (**3**) and glycerol (**4**).

<Insert Figure 2>

The alcohol reacts with the fatty acids to form the mono-alkyl ester (biodiesel) and crude glycerol. The reaction between the bio lipid (fat or oil) and the alcohol is a reversible reaction so excess alcohol must be added to ensure complete conversion. Properties of CSNL bio diesel is shown in table2.

<**Insert table2**>

3. MATERIAL

3.1 n-Pentanol

n-Pentanol or n-Pentanol is a primary alcohol and the chemical formula is C4H12O. It has the ability to corrode plastics and rubber when comes in contact with it. It is miscible with many organic solvents, and incompatible with strong oxidizers. It is used as a direct solvent and as an intermediate in manufacturing other organic chemicals. n-Pentanol has been proposed as a substitute for diesel fuel and gasoline. Since alcohol content has more oxygen, it is mostly used as additive in biodiesel because biodiesel requires plenty of oxygen molecule to produce high rate of combustion. As a result n-Pentanol is used as additives in biodiesel to increase the rate of combustion.

4 TESTING AND ANALYSIS OF BIODIESEL

4.1 TESTING A BIO DIESEL BLENDS

Blends of biodiesel and n-Pentanol are products most commonly distributed for use in the retail diesel fuel marketplace. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix:

- 100% biodiesel is referred to as B100
- 85% biodiesel, 15% n-Pentanol is labelled B80
- 100% conventional diesel.

These sample are used to investigate the performance and emission characteristics of the biodiesel. Each sample is tested in the engine test rig and the obtained results are compared and the best sample is selected for use.

4.2 DESCRIPTION OF THE TEST ENGINE

The engine used is Kirloskar TAF1 single cylinder, naturally aspirated, four stroke, air cooled, 17.5:1 compression ratio, diesel engine, and the maximum engine power is 4.4 kW at 1500 rpm. A Kirloskar A.C Alternator with resistance bank loading arrangement is also incorporated. The cylinder pressure was measured using a kistler 6613CA piezo electric transducer with corresponding charge amplifier and data acquisition systems. Exhaust gas temperature were measured directly from the thermocouples (Cr–Al) attached to the corresponding passages shown in fig 3

<Insert Figure 3>

4.2.1 Engine specification

The test engine used in this investigation was a Kirloskar TAF-1 Vertical, 4-Stroke cycle, single cylinder, totally enclosed, air cooled, and high speed compression ignition diesel engine. Lists the engine specifications and operating conditions used in this study.

<Insert Figure 4>

4.2.2 Engine Exhaust instruments

The engine exhausts NO, CO, HC, CO2 were measured with AVL-444 Di gas analyser, and the exhaust emissions were measured at 250 mm from the exhaust valve. A CLD Detector for NO emission, a Flame Ionization Detector (FID) analyser for HC, a Non Dispersive Infrared (NDIR) analyser For CO, CO2.The smoke opacity was measured by AVL-437C smoke meter after reducing the pressure and temperature in the expansion chamber. The performance and emission characteristics were evaluated for three trails and average are taken for analysis.

<Insert Figure 5>

4.2.3 TEST REPORT FOR BIO DIESEL BLENDS

90% biodiesel, 10% n-Pentanol

Engine Details:
IC Engine set up under test is Kirloskar TV1 having power 5.20 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 17.50, Swept volume 661.45 (cc).

Combustion Parameters:
Specific Gas Const (kJ/kgK): 1.00, Air Density (kg/m^3): 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.26, Number of Cycles: 5, Cylinder Pressure Reference: 3, Smoothing 2, TDC Reference: 0
Performance Parameters:
Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe dia (mm): 12.40, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m^3): 896, Calorific Value of Fuel (kj/kg): 33336.

95% biodiesel, 5% n-Pentanol

Engine Details:
IC Engine set up under test is Kirloskar TV1 having power 5.20 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 17.50, Swept volume 661.45 (cc)
Combustion Parameters:
Specific Gas Const (kJ/kgK): 1.00, Air Density (kg/m^3): 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.24, Number of Cycles: 5, Cylinder Pressure Reference: 2, Smoothing 2, TDC Reference: 0
Performance Parameters:
Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe dia (mm): 12.40, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m^3): 896, Calorific Value of Fuel (kj/kg): 34346.

5. Results and Discussion:

<Insert Figure 6>

<Insert Figure 7>

<Insert Figure 8>

In Figure 6, a slight drop in efficiency was found with cashew nut shell biodiesel when compared with pure diesel. This drop in thermal efficiency must be attributed to the poor combustion characteristics of CNSL biodiesel due to high viscosity. It was experimental that the brake thermal efficiency of 95% biodiesel and 5% n-pentanol had better brake thermal efficiency than compared with 90% biodiesel and 10% n-pentanol. So 95% biodiesel and 5% n-pentanol can be suggested as best blend for biodiesel preparation with diesel.
In Figure 7 and 8 shows the comparison of CO and HC emissions for 95% biodiesel and 5% n-pentanol and 90% biodiesel and 10% n-pentanol at standard engine specification. The experimental results show that for all the blends, the HC emissions were lower at part load, but increases with increase in load. The HC emission for pure cashew nut shell biodiesel at maximum load was 40 ppm, where it was decreased by 0.15% and 0.25% . This may be due

to the fact that all the biodiesel contain oxygen in their chemical composition. This favours comparatively better combustion for biodiesel when compared with diesel

CONCLUSION:

After our experiment analysis it has been confirmed that cashew nut shell oil can be profitably used as resource to obtain biodiesel. Performance rate and Emission characteristics is analyzed by adding n-Pentanol as an additive with cashew nut shell oil. The result is observed and listed below.

1. Brake thermal efficiency for cashew nut shell biodiesel is 20.76178. By adding 15% of n-Pentanol to cashew nut shell biodiesel the brake thermal efficiency increases to 22.04268.
2. Brake specific fuel consumption for cashew nut shell biodiesel is 0.468786. By adding 15% n-Pentanol to cashew nut shell biodiesel specific fuel consumption decreases to 0.44469.
3. Exhaust gas temperature for cashew nut shell biodiesel is 258.2 by adding 15% of n-Pentanol to cashew nut shell biodiesel exhaust gas temperature decreases to 255.2.
4. The CO emission for Cashew nut shell biodiesel is 0.06875. By adding 15% of additive n-Pentanol to Cashew nut shell biodiesel the CO emission is reduced to 0.066
5. The Hydrocarbon emission for Cashew nut shell biodiesel is 47.5. By adding 15% of additive n-Pentanol to Cashew nut shell biodiesel the Hydrocarbon emission is reduced to 42.5
6. The NOx emission for Cashew nut shell biodiesel is 347 by adding 15% of additive n-Pentanol to Cashew nut shell biodiesel the NOx emission is reduced to 315.
7. The smoke emitted by Cashew nut shell biodiesel is 46.5. By adding 15% of additive n-Pentanol to Cashew nut shell biodiesel the smoke emission is reduced to 43.

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List of Figures:

Figure 1: Cashew nut shell Plant

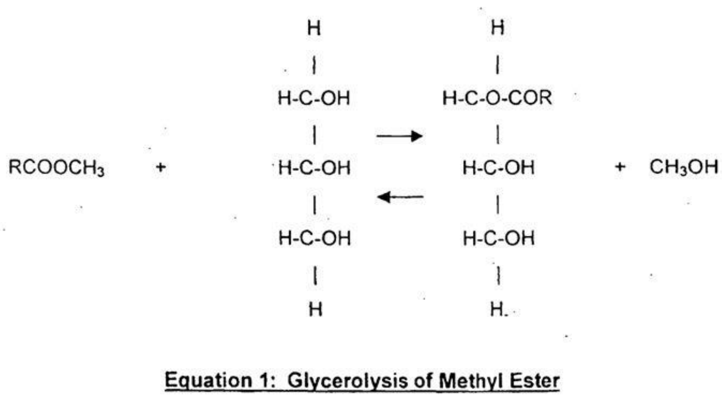

Figure 2: Equation of Transesterification Process

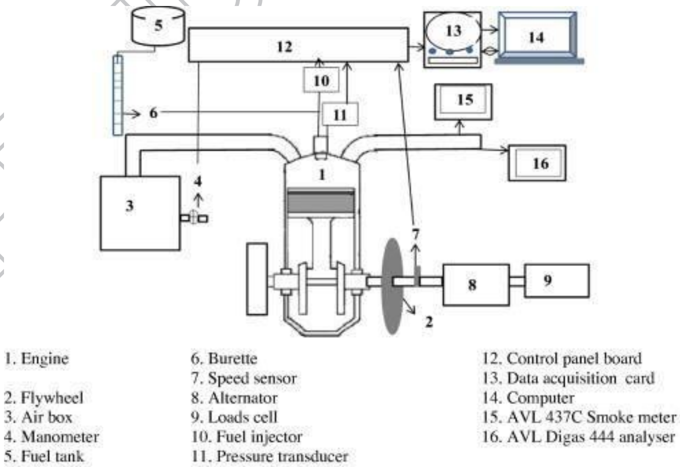

Figure 3: Schematic diagram of test engine

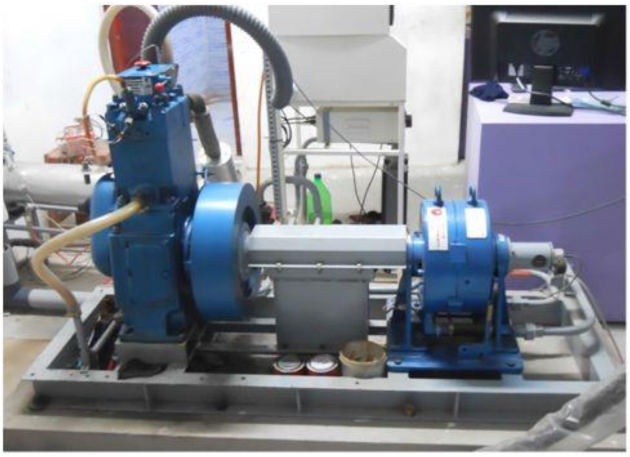

Figure 4: Kirloskar Engine

Figure 5: AVL Analyzer

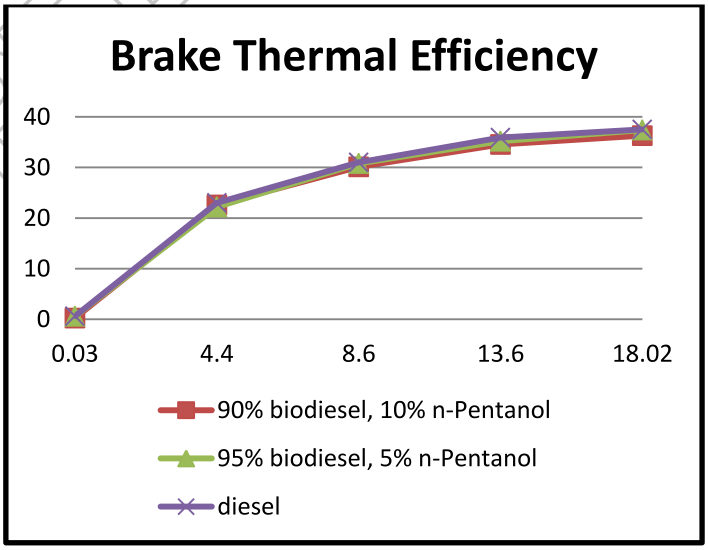

Figure 6: Brake thermal efficiency

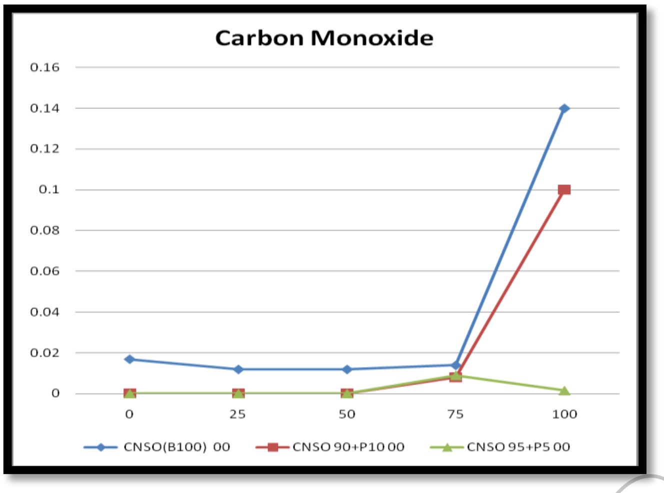

Figure 7: Carbon Monoxide

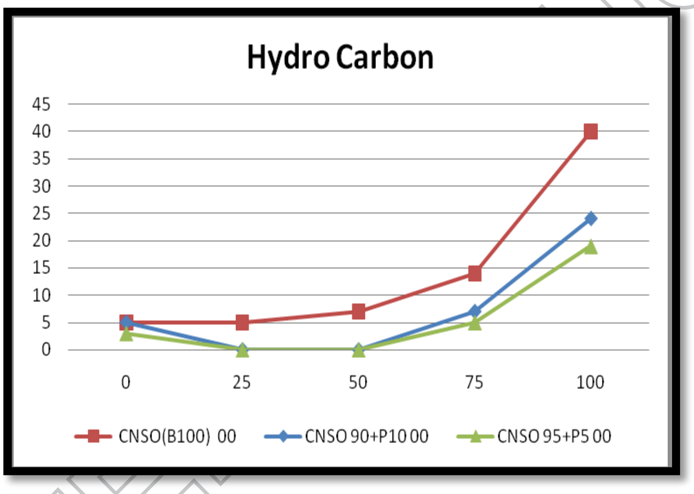

Figure 8: Hydrocarbon

Table .1 Chemical Composition of Cashew nut shell Oil

Chemical Composition	Cashew nut shell Oil
Moisture	6.20%
Protein	18.00%
Fat	38.00%
Fibre	15.50%
Ash	5.30%

Table .2 Properties of Cashew nut shell Oil and CNSL bio diesel

Property	Property Cashew nut shell oil	CNSL –biodiesel
Density kg/m³	914	904
Kin. Viscosity CST(40°)	31.2	6.9
Gross calorific value MJ/kg	39.66	33.33
Water content mg/kg	822.8	822.8
Cetane Number	25-41	60.83

Table .3 Properties of n-Pentanol

Property	n -Pentanol
Melting point	-89°C
Boiling point	117-118°C
Specific Gravity	0.810-0.812
Vapour density	2.6
Auto ignition	343°C
Flash point	26-29°C