IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EXPERIMENTAL STUDIES ON DIESEL ENGINE FULLED WITH CASHEW NUT SHELL OIL AS AN ALTERNATE FUEL

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DOI: 10.5281/zenodo.828935

ABSTRACT

This paper evaluates the novel use of cashew nut shell oil (CNSO) as an alternative fuel for diesel. Biodiesel is produced free from environment, and different types of vegetable oils and animal fats. It has highly oxygenated, non-toxic, sulfur free.The renewable fuel that can be adoption in diesel engines without any change. Direct injection diesel engine have been experimentally examine with CNSO methyl esters and its blends (C10, C20 and C30) with diesel fuel. Engine performance parameters namely Brake specific fuel consumption, Brake thermal efficiency, combustion and exhaust emissions of CO, HC,CO2, NOx and smoke density were determined for wide range of loading conditions and at constant engine speed of 1500 rpm. The result denotes that there is a slight decrease in brake thermal efficiency and increase in specific fuel consumption for all the blended fuels when compared to the base fuel. The substantial reduction in carbon monoxide, unburned hydrocarbon and smoke density were recorded for all the blended fuels as well as with neat biodiesel and slightly increased with base fuel. But, in the case of oxides of nitrogen, there is a slight increase for all the blended fuels and with neat biodiesel when compared to diesel fuel.

KEYWORDS: Bio diesel ,CNSO ,Performance, Combustion and Emission.

NOMENCLUTURE

BSFC - Brake specific fuel consumption
BTE- Brake thermal efficiency
EGT- Exhaust gas temperature
CO - Carbon monoxide
HC- Hydrocarbon
NOx- Oxides of Nitrogen
kW- Kilowatt
Kg - Kilogram
EGT- Exhaust gas temperature
CO -Carbon monoxide
HC- Hydrocarbon
NOx- Oxides of Nitrogen
CA- Crank angle
CNSO-Cashew nut shell oil

I. INTRODUCTION

Bio fuels are produce from animal fats or vegetable oils that come from plants such as jatropha, soybean, sunflowers, corn, olive, peanut, palm, coconut, safflower, canola, sesame, cottonseed, etc. Once these fats or oils are purified from their hydrocarbons and then mixed with alcohol like methanol, biodiesel is transport to life from this chemical reaction. These raw materials can either be mixed with pure diesel to make various fractions, or used alone. Despite one's mixture preference, biodiesel will release smaller number of pollutants (carbon monoxide particulates and hydrocarbons) than conventional diesel, because biodiesel burns both cleanly and more efficiently. Even with regular diesel's reduced quantity of sulfur from the ULSD (ultra-low sulfur diesel) invention, biodiesel exceeds those levels because it is sulfur-free. The use of jatropha biodiesel in a conventional diesel engine decreases its torque and brake thermal efficiency decrease and Cylinder peak pressure increases and ignition delay period decreases with the increase in biodiesel share in the blended fuels.

Gaurav Paula eatl. [1] Studied the use of GTL diesel fuel in unmodified engines. It enables significant reductions on HC,CO and PM emissions without compromising NOx emissions, with compared to diesel and bio- diesel fuels.

H. Sajjad eatl.[2] evaluated The lower air fuel ratio which is caused by the high fuel injection results in a higher smoke emission. The fuel consumption also affects the smoke emission. The combustion of MPO-diesel blends is slower than that of diesel is due to the low cetane number, higher density, and poor volatility. The HC and CO emissions were higher for the MPO-diesel blends than diesel. Debalaxmi Pradhan eatl. [3] investigated with methyl esters of beef tallow as neat biodiesel and its blends, it was found that CO and HC emissions were lower than that of pure diesel. This is due to higher oxygen content of biodiesel, which would result in better combustion and maximum cylinder temperature. D.John Panneer Selvam eatl. [4]experiments conducted on diesel engines with neat mango seed oil that oil is converted into their respective methyl ester through transesterification process. The combustion starts earlier for biodiesel and its blends than diesel. The peak cylinder pressure and heat release rate of biodiesel and its blends are lower than diesel. It is concluded that optimized blend is B25 with respect to performance, emission and combustion characteristics for all loads compared with diesel. K. Vijayaraj eatl. [5] By increasing EPS content, lambda, soot and O2 increased. While NOx and CO2 decreased significantly Using the EPS content of 25 g/L for bio diesel.The Brake specific fuel consumption and brake thermal efficiency values remained approximately constant with increasing the speed can be concluded that the inclusion of 50 g EPS in 1 L biodiesel could be a promising strategy in order to achieve emission reduction from diesel engines and improving the engine performance. Pouya Mohammadi eatl.[6]studied the Cetane number is improved diethyl ether (DEE) blends with kerosene and diesel . The BTE has improved with DEE addition to diesel fuel and it increases with increase in DEE percentage in diesel fuel. The BSFC of DE15D was observed less than other blends and neat diesel. The BSFC of DE20D and DE25D was higher than DE15D blends. . Bhupendra Singh eatl. [7] The usage of neat cashew nut shell oil (CSNO) as a fuel in direct injection diesel engine improves the performance of cashew nut shell oil as fuel in a DI diesel engine. This is mainly due to lower viscosity of camphor oil and its better ignition properties. Improved atomization vaporization and mixing are obtained with camphor oil addition resulting in complete combustion. the performance of neat CSNO can be improved significantly by blending camphor oil and CMPRO 30 blend can be used as a substitute for diesel. K.R.Patil eatl. [8] evaluate the Performance, emission and combustion characteristics were studied by operating the engine with cashew nut shell oil as base fuel blended with diesel and separately with other secondary fuels like oxygenates, alcohols and vegetable oils in various proportions by volume it is identified that DEE30 among oxygenates, BUTANOL30 among alcohols and CMPRO30 among other vegetable oils blended, provides optimum engine performance. Among these three fuels, DEE30 and CMPRO30 provide engine performance, combustion and emissions on par with base diesel engine. Singh Harpreet eatl. [9] studied the recovery of ester by transesterification of waste cotton seed oil with methanol is affected by process parameters such as catalyst concentration and reaction temperature. K. Ganesh Babu eatl. [10] Compare to all other oils sources like algae.Ithas a more suitable saturated and unsaturated composition of biodiesel (FAME) production. The level of un saturation in the algae caused by parameters like light intensity, temperature and doubling time (growth). It also depends on the wet or dry biomass used in the transesterification process. The higher level of un saturation will reduce particulate emissions, but NOx emission was increased. S. Mohite1 eatl [11] Compared Brake thermal efficiencies of biodiesel blends were found to be decreased in the range of 0.9 to 6.05% than that of diesel. BSFC also increased in the range of 1.13% 11.49% for biodiesel blends and it was found that it increases with the proportions of biodiesel in biodiesel and its blends. Sanjay Mohite eatl. [12] studied higher yield has been achieved with 2 wt% KOH catalytic concentration in comparison to 1 wt% KOH and 1.5 wt% KOH catalytic concentration. Higher yield has been achieved with 60 minutes reaction time in comparison to 30 and 45 minutes reaction time. S. K. Sanjeeva eatl [13] found that increases in HC, CO and CO2 were co-relate with increases in DT-CNSL in the blends, and at higher loads there was no significant difference between diesel and DT-CNSL blends. This clearly indicates that at higher loads, DT-CNSL blends can withstand load and are more suitable fuels compared to diesel. A. Velmurugan eatl [14] Studied the BSFC increased for the TC-CNSL blends compared to diesel fuel. The BSFC for B100 was 25% higher than that of the diesel fuel at full load. The BTE decreased with increasing concentration of TC-CNSL. The BTE of B100 and B20 are respectively 29.23% and 34.50%, lower than that of diesel at full load.The higher viscosity of biodiesel is reduced by preheating and the performance and emission of this preheated CNSL methyl ester has been improved.Velmurugan eatl [15]l investigated with DT-CNSL blends in a diesel engine with 100% biodiesel, due to more viscosity, the engine suffered various problems like wild fluctuations of speed, more emissions and corrosion, me specially at higher loads. The higher viscosity and lower volatility of CNSL lead to poor mixture formation and hence lower brake thermal efficiency (BTE) and higher emission levels.

II. PRODUCTION OF BIODIESEL FROM CASHEW NUT SHELL OIL

In this study, one-step transesterification of cashew nut shell oil with methanol was performed as KOH as catalyst. The diesel fuel was purchased from local Indian Oil fuel supply station and CNSO was collected from cashew industry of Kerala India. CNSO was converted into methyl esters through base-catalyzed transesterification with methanol in the presence of KOH as catalyst. Before transesterification, CNSO was heated to around 100-120°C for 1 hour and then sediments and impurities were filtered with cloth filter. After this process, a sample of 750 ml of, CNSO 250 ml of methanol and 2 g of KOH were placed in a 1000 ml flat-bottom flask integrated with a magnetic stirrer heater, digital thermometer. This mixture was stirred rigorously and heated to 60 C for 5-6 hours, and then it was allowed to cool to room temperature for 12 hour. Then the ester and glycerol layers were separated in a separator funnel. Finally methyl ester of CNSO was purified with distilled water and drying to room temperature.

Fig: 2 .1. Cashew nut seeds

Fuel Properties

The properties of diesel fuel, cashew nut shell oil methyl ester (CNSO) are given in Table 1. It is shown that the viscosity of biodiesel is obviously higher than that of diesel fuel. The density of the biodiesel is approximately 13.4% higher than that of diesel fuel. The lower heating value is around 425% lower than that of diesel fuel. Therefore it is required to increase the fuel quantity to be injected into the combustion chamber to produce same quantity of power. Fuels with fire point above 52°C are regarded as safe. Thus biodiesel with high fire point (163°C) is an especially safe fuel to handle and storage. Formation of biodiesel is preferable to choice as far as safety is concerned. The fuel-borne oxygen in biodiesel is 11-12%, which improves combustion processes effectively.

Table: 1 The properties of diesel fuel, cashew nut shell oil methyl ester (CNSO)

Properties	CNSO	Diesel	C10	C20	C30
Density(kg/m$^{3)}$	956.4	822	842	855	867
Specific gravity	0.956	0.822	0.842	0.855	0.867
Viscosity at 40 ^{0}c	62.2	2.52	8.488	14.45	20.424
Flash point (^{0}C)	217	55	71.2	87.4	103.6
Calorific value (kJ/kg)	38,681	42,700	42118.1	41736.2	41354.3
Fire point (^{0}C)	233	71	87.2	103.4	119.6

III. EXPERIMENTAL SET-UP AND PROCEDURE

A four stroke, single cylinder, direct injection, naturally aspirated, water cooled, Kirloskar TV-1 model diesel engine was used in this study. The schematic diagram of experimental set-up is shown in Figure 2.

Fig: 3.1 .Computerized engine setup

The fuels used in this study include diesel fuel, biodiesel (CNSO) and biodiesel blends. The experiments were carried out by using neat diesel fuel as the base line fuel(denoted as Diesel Fuel), 10% biodiesel + 90% diesel fuel (denoted as C10), 20% biodiesel + 80% diesel fuel(denoted as C20), 30% biodiesel + 70% diesel fuel (denoted as C30) at different engine loads from 0% to 100% rated engine load. Before running the engine to a new fuel, it was allowed to run for sufficient time to consume the remaining part of fuel from the previous experiment. The engine was started initially with diesel fuel and warmed up to obtain its base parameters. Then, the same tests were performed with biodiesel and its blends. For each test fuel and in each load approximately three times readings were taken to get an average value. When the engine reaches the stabilized working condition, parameters like fuel consumption and load were measured. The fuel consumption was measured with a burette (20ml volume) and a stopwatch. The exhaust gas temperature was measured with a K-type thermocouple located on the exhaust pipe line. The performance and emission parameters of diesel and its Bio diesel blends (C10,C20,C30) were determined and comparison with baseline. Performance parameters namely, brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were computed. Similarly exhaust emissions like carbon monoxide (CO),unburned hydrocarbon (HC) and oxides of nitrogen (NO**x**) were measured using a non-dispersive infrared analyzer (NDIR) (Make: AVL Di-gas Analyzer) and smoke density was measured with an AVL smoke meter.

IV. RESULTS AND DISCUSSION

1. Engine Performance Characteristics

Brake Specific Fuel Consumption

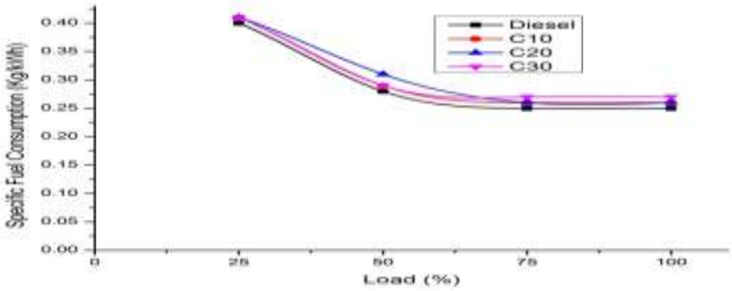

Fig: 4.1 .Variation of Brake specific fuel consumption with Load

The variation of BSFC with respect to load for diesel fuel, biodiesel and its blends is shown in Figure 4.1 . The brake specific fuel consumption is defined as the ratio of mass fuel consumption to brake power. The specific fuel consumption in general increases at low load, decreases at medium load and increases again at higher load. For all the test fuels, the specific fuel consumption decreases with an increase in load. Among the fuels tested the lowest BSFC values are obtained with diesel fuel due to low fuel consumption rate and high brake power.

The specific fuel consumption in general, was found to increase with increasing proportion of biodiesel in the test fuels under all loading conditions. This is due to lower calorific value, higher viscosity and density of biodiesel in comparison with diesel fuel. As the density of biodiesel was higher than that of diesel fuel, which means the same fuel consumption on volume basis resulted in higher specific fuel consumption in case of biodiesel. For all the test fuels, the specific fuel consumption values are higher at low load and decreases to minimum values when load increases because of the lower calorific value of biodiesel. The specific fuel consumption for diesel fuel, C10,C20 and C30 are 0.25,0.26,027and 0.28Kg/kw-hr respectively at full load of the engine.. The results indicated that specific fuel consumption for neat diesel and its blends C10, C20 and C30 were higher than that of diesel fuel.

Brake Thermal Efficiency

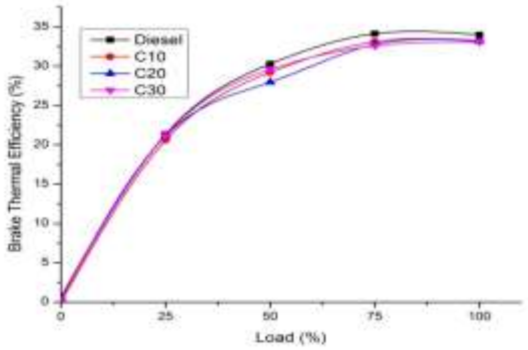

Fig: 4.2. Variation of Brake thermal efficiency with Load

The variation in BTE of the engine with diesel fuel, biodiesel and its blend is shown in Figure 4.2. Thermal efficiency is the ratio between the power output and the energy introduced through fuel injection, the thermal efficiency in general, decreases with increasing proportion of biodiesel in the test fuels. This is due to the methyl esters of vegetable oils and animal fats are having higher viscosity, density and lower heat value than the diesel fuel. The higher viscosity leads to decreased atomization, fuel vaporization and combustion and hence the thermal efficiency of biodiesel is lower than that of diesel fuel. The brake thermal efficiency of diesel fuel,C10,C20 and C30 are 34.00%,33.24%.33.86% and 33.17% respectively at full load of the engine. The BTE of C20 blended fuel is very close to diesel fuel. Thus the difference in BTE between diesel fuel and C20 blend is very significant at maximum load. Fuel consumption increases due to higher density and lower heating value consequently, brake thermal efficiency decreases. However the BTE of blended fuels is higher than that of neat biodiesel.

Mechanical Efficiency

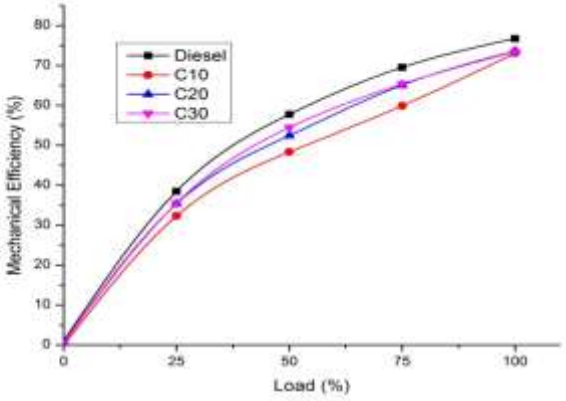

Fig: 4.3. Variation of mechanical efficiency with Load

The comparison of Mechanical efficiency for various biodiesel blends with respect to load shown the Fig 4.3. From the plot it is observed diesel and its blends like C10, C20 ,C30 nearly equal at full load conditions. But considerable improvement in mechanical efficiency was observed by the blend C20 is 73.63% because of lowest frictional powers compared to diesel. Because of sufficient lubricating property of this blend frictional powers are reduced drastically and considerable improvement in mechanical efficiency has been observed and calorific value of this blend is more compared to other blends.

Exhaust Gas Temperature

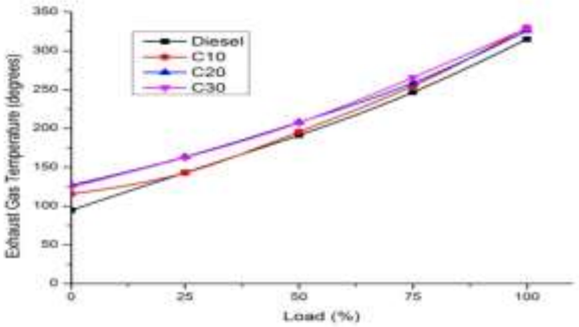

Fig: 4.4.Variation of exhaust gas temperature with Load

This fact is reflected in brake thermal efficiency and brake specific fuel consumption as well. When biodiesel concentration is increased, the exhaust gas temperature increases by a small value.. The exhaust gas temperature increases with increase in load for all tested fuels. The increase in exhaust gas temperature with load is obvious from the fact that more fuel is required to take additional load. Exhaust gas temperature is an indication of the extent of conversion of heat into work, which happens inside the cylinder. It is noted that the exhaust gas temperature using different fuels at various load levels are nearly the same. Exhaust gas temperature increases with increase in power for all the fuels. As the biodiesel fuel concentration is increased, the exhaust gas temperature also increased. The higher exhaust gas temperature is 325°C at higher power for C20. This increase in the exhaust gas temperature may be due to the high viscosity of the biodiesel.

V. COMBUSTION ANNALYSIS

1. *Cylinder Pressure*

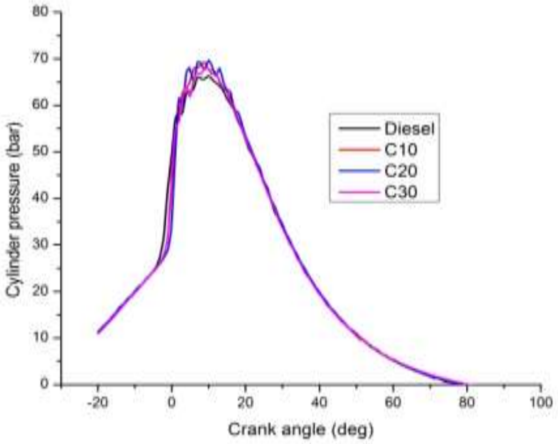

Fig:5.1 Variation of cylinder pressure with crank angle

Shows fig 5.1. The variation of cylinder pressure with crank angle for diesel, biodiesel and its blends at 1500 rpm and full load conditions. Peak pressure mainly depends upon the combustion rate in the initial stages, which is influenced by the fuel taking part in uncontrolled heat release phase. The combustion process of test fuel is similar, consisting of a phase of premixed combustion followed by a phase of diffusion combustion. Premixed combustion phase is controlled by the ignition delay period and spray envelope of the injected fuel . Therefore, the viscosity and volatility of the fuel have a very important role to increase atomization rate and to improve air–fuel mixing formation. The cylinder peak pressure because of the high viscosity and low volatility of biodiesel and its blends is slightly lower than that of diesel fuel. It is observed that the peak pressures of 70.872, 70.553, 69.914, 69.712 and 68.982 bar were recorded for Diesel and its blends C10, C20, C30, and respectively. However, the cylinder peak pressure of C20 is close to diesel due to the improvement in the preparation of air–fuel mixture as a result of low fuel viscosity.

2. *Heat Release Rate*

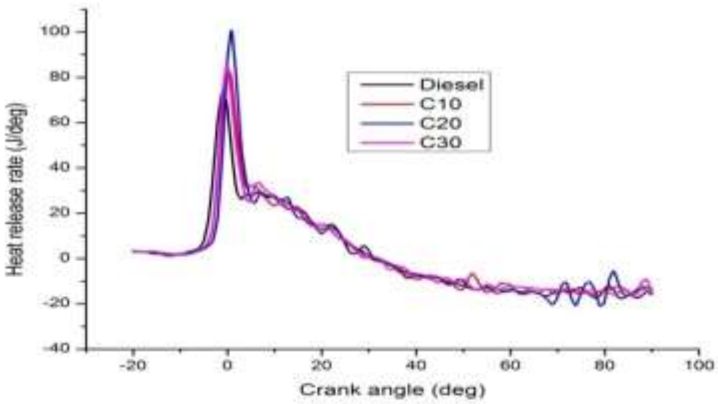

Fig: 5.2 Variation heat release rate with crank angle

The variation of heat release rate with crank angle at full load for diesel, biodiesel and its blends is shown in figure 5.2. It is observed from the results that the heat release rate for biodiesel and its blends is lower compared to diesel fuel. This may be due to lower calorific value of biodiesel and its blends. However C20 gives more heat release rate than other blends. On the other hand, peak heat release rate for C100 is low compared to C20 and this may be due to lower volatility and higher viscosity of B100. The maximum heat release rate of diesel fuel and its blends C10, C20, C30 is 115.63, 112.12, 109.26, 99.24 kJ/m3 deg respectively. . A Closer analysis of the heat release rate at higher engine load showed proper utilization of C20 inside the combustion chamber of the engine.

VI. EXHAUST EMISSION CHARACTERISTICS

1. Carbon Monoxide

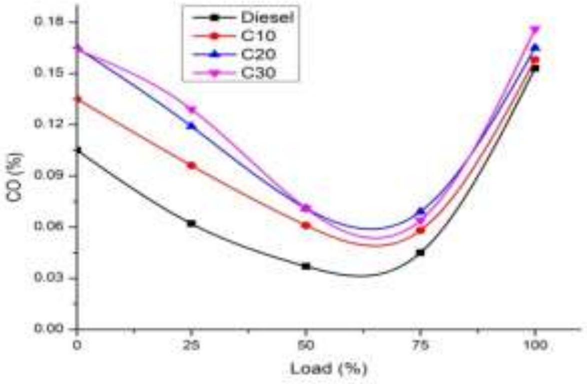

Fig: 6.1 Variation of carbon monoxide with Load

The variations of CO emission with respect to load of the engine. The air–fuel mixing process is affected by the difficulty in atomization of biodiesel due to its higher viscosity. Also, the resulting locally rich mixtures of biodiesel cause more CO to be produced during combustion. However, biodiesel that contains more number of oxygen atoms leads to more complete combustion. At low and middle engine loads, the percentage of CO emissions of biodiesel and its blends is higher compared to diesel. This may be due to relatively poor atomization and lower volatility of biodiesel. As a result, some of the fuel droplets may not get burned. When these unburned droplets mix with the hot combustion gases, oxidation reactions occur, but do not have enough time to undergo complete combustion. At full load, the percentage of CO emission of diesel is 0.153 but the percentage of CO emission of C10, C20, and C30 is 0.058, 0.165, and 0.176 respectively. It indicates that the combustion efficiency improves with the blend of CNSO with diesel and reduction in CO emission when compared to neat diesel. Moreover, higher fuel quantity at higher loads also causes higher CO emission. Since the increase in the quantity of diesel in the blend improves the performance from the emission point of view, the blend ratio is decided based on the amount of diesel to be replaced or the level of emission that can be tolerated.

2. Hydrocarbon

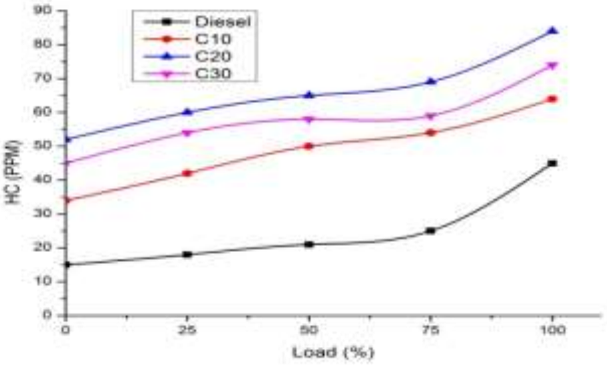

Fig: 6.2. Variation of hydro carbons with Load

The variation of HC emission with load is shown in fig no 6.2. The emission of HC decreases as the diesel is substituted by biodiesel. Cetane number of biodiesel is higher than diesel, and due to this it exhibits shorter delay period, which contributes to better combustion of fuel resulting in low emission of HC. Another reason can be the oxygen molecules present in the structure of biodiesel, which helps complete combustion of the fuel and hence decreases HC emission. At full load diesel had highest HC emission of 45 ppm. where as HC emission indicates better combustion of CNSO. The highest HC emissions are 54, 84, and 74 ppm for C10, C20, and C30 respectively.

3. Oxides Of Nitrogen

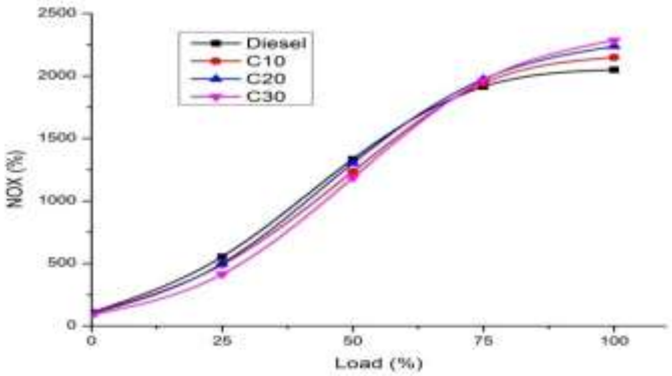

Fig: 6.3. Variation of Oxides of nitrogen with Load

The variation of NOx with load for diesel, biodiesel and its blends is shown in fig no 6.3. Three factors that affect the formation of NOx in the cylinder are oxygen content, combustion flame temperature and reaction time. NOx emissions of biodiesel and its blends are slightly higher than those of diesel fuel. The higher temperature of combustion and the presence of oxygen with biodiesel cause higher NOx emissions, especially at high engine loads. NOx emissions were found to increase due to the presence of extra oxygen in the molecules of biodiesel blends. However, the biodiesel with higher cetane number had comparable NOx emissions with the diesel fuel. A higher cetane number would result in a shortened ignition delay period, thereby allowing less time for the air–fuel mixing before the pre-mixed combustion phase. Consequently, a weaker mixture would be generated and burnt during the premixed combustion phase resulting in relatively reduced NOx formation. The highest NOx emissions are 1942, 2238 and 2285ppm for C10, C20, and C30 respectively. From the figure, it is clear that at full load, NOx emissions are higher than that of diesel whereas for C30, the NOx emission was 5.88% higher. NOx emission is the most harmful gaseous emissions from the engines.

4. Carbon Dioxide

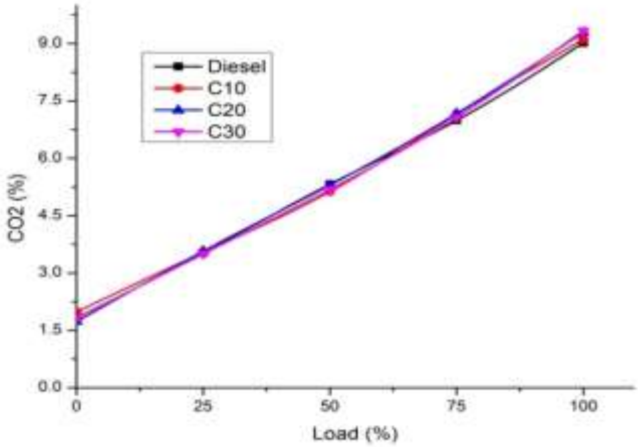

Fig: 6.4 Variation of carbon dioxide with Load

The variation of CO2 emissions with load is shown in fig no 6.4. It is observed that the CO2 emission increases with load. The amount of carbon dioxide in the exhaust gas is a measure of combustion. Under ideal conditions any hydrocarbon fuel should give CO2 and water only on combustion. It is observed that at peak load the neat CNSO operation gives out 2.74% of CO2 emission and diesel emits 6.8% of CO2. The 30 blend has slightly higher CO2 % emission of 8.8% due to combustion improvements.

5. Oxygen

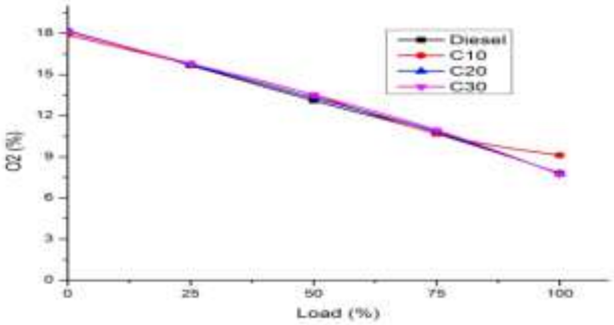

Fig: 6.5Variation of oxygen with Load

Shows fig no.6.5 The variation of Oxygen content that can be slightly arises the properties to show the identification of the engine performance that can be slightly arises the proportion of the material of the CNSO and its blends is shown in figure 11. It is clear that oxygen present in the exhaust gas is decreases as the load increases. It is Obvious that due to improved combustion, the temperature in the combustion chamber can be expected to be higher and higher amount of oxygen is also present, leading to formation of higher quantity of NOx, CNSO blends. In presence of oxygen atoms in the straight vegetable oil based alkyl ester helps to combustion of fuel is completely and reduces smoke substantially oxygen content in exhaust emissions was higher for different blends.

6. Smoke Opasity

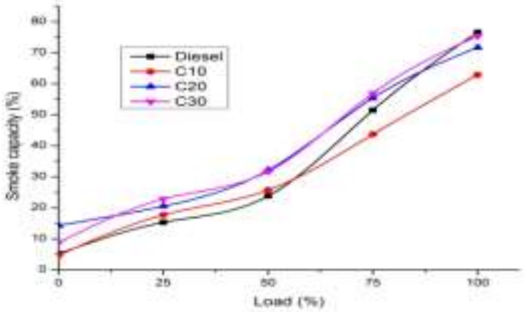

Fig: 6.6 Variation of Smoke oapcity with Load

Shows fig no 6.6 the variation of smoke Opacity with load for diesel, biodiesel and its blends.. At low and middle engine loads the smoke density is higher than diesel. This is due to the high viscosity of biodiesel, which results in poor atomization and locally rich mixtures at part load operations. But at high engine loads, smoke density of biodiesel and its blends is lower than diesel fuel. Smoke is mainly produced in the diffusive combustion phase; the oxygenated fuel blends lead to an improvement in diffusive combustion for biodiesel and its blends. The highest smoke emissions are 62.9, 71.7 and 75.4 for C10, C20, and C30 respectively which lower than the diesel. Reduction in smoke emission of about 4 % is recorded at full load for the C20 blend. Another reason of smoke reduction, when using biodiesel is due to the lower C/H ratio and the absence of aromatic compounds as compared to diesel. The carbon content in biodiesel is lower than diesel fuel. The more carbon a fuel molecule contains, the more likely is to produce soot. Conversely, oxygen within a fuel decreases the tendency of a fuel to produce soot.

VII. CONCLUSIONS

In the present investigation, the performance, emission and combustion characteristics of a direct injection, compression ignition engine fueled with CNSO methyl ester and its blends have been analyzed and compared with diesel fuel. The biodiesel is produced from CNSO oil by a method of transesterification. The tests for properties of biodiesel demonstrate that almost all the important properties of biodiesel are in close with the diesel fuel. Thus the diesel engine can perform satisfactorily on methyl ester of CNSO and its blends with diesel fuel. The results of the present work are summarized as follows:

1. The BSFC increases with increase in percentage of biodiesel in the blends due to lower heating value of biodiesel.
2. The BTE of C20 is closer to diesel at all loads.
3. It is observed that there is a significant reduction of HC for biodiesel and its blends at all engine loads.
4. The emission of NOx is higher than diesel for biodiesel and its blends, but for C20 slight increase of only 5.88% is observed at full load.
5. Reduction in smoke emission for biodiesel and its blends at high loads whereas, for C20 decrease of 14.6% is observed at full load.
6. The cylinder pressure and rate of pressure rise for CNSO blends are slightly higher than those with the fuel.
7. HRR are higher for CNSO blends compare to diesel fuel .The HRR for B20 is higher than the diesel.

On the whole, CNSO and its blends can be used as an alternative fuel in diesel engines without any engine modifications. It gives lower smoke emissions when compared with the diesel fuel. But the addition of higher percentage of biodiesel blends with diesel fuel which decreases brake thermal efficiency and increases specific fuel consumption.

From this study, it is concluded that optimized blend is C20 with respect to performance, emission and combustion characteristics for all loads compared with diesel and it could be used as a viable alternative fuel in a single cylinder direct injection diesel engine without any modifications and thereby saving 20% of the precious neat diesel fuel.

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CITE AN ARTICLE

Sivanjaneyulu, G.V.V.N, and V. Dhana Raja. "EXPERIMENTAL STUDIES ON DIESEL ENGINE FULLED WITH CASHEW NUT SHELL OIL AS AN ALTERNATE FUEL." *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY* 6.7 (2017): 433-43. Web. 15 July 2017.