Experimental Investigations On CI Diesel Engine With Varied Combustion Chamber Designs (HCC And SDCC) Using Neem Biodiesel And Calcium Carbonate (Caco3) Nano Fluid Additive

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Abstract : *The dependency on diesel engine is more due to its less cost when compared to petrol fuels, using of fossil fuels in a larger quantities will leads to the scarcity, in order to overcome this problem alternative fuels are introduced. Biodiesel is an alternative source for diesel fuel in C I Diesel engines due to its significant performance and Environmental benefits From previous researches it is learnt that neem biodiesel will be used as an alternate fuel but in percentages (B10,B20..). But in this work an attempt is made using neem biodiesel (B100) with different combustion chambers that are hemispherical combustion chamber (HCC) and shallow depth combustion chambers (SDCC) to find the better combustion characteristics and to reduce heat losses to obtain maximum efficiency in diesel engine. Neem biodiesel alone will not solve the dependence on alternate fuel because it contains high viscosity, density and low calorific value, to improve the properties of neem biodiesel nano fluid additive is added to it to make biodiesel as a high calorific fuel. calcium carbonate is best suited as a nano additive due to its beneficial properties. An experimental investigation are carried out on a single cylinder, four stroke, naturally aspirated, direct injection and water cooled diesel Engine with a compression ratio of 17.5:1 and brake power output of 5.2 kW at 1500 rev/min using neem biodiesel and caco$_3$ nano fluid in two proportions (3gm/l and 5gm/l) due to its less density and higher % of oxygen and lower % of carbon content in caco$_3$. The performance and emissions are recorded for diesel, neem biodiesel and neem biodiesel (B100) with caco$_3$ blends. The test results shown that Neem biodiesel with calcium carbonate proportions are a promising alternative fuel having comparable characteristics with diesel fuel.*

Keywords: Diesel Engine Neem biodiesel, Calcium Carbonate Nanofluid additive, Types of combustion chambers and Engine Emissions.

1. INTRODUCTION

CI engines are designed to with stand the high pressures and are heavier than SI engines. Diesel engine plays a vital/lead role in power generation, transportation and industrial sectors due to its properties of ease handling, inexpensive and higher efficiency/output, diesel engines are of highly used in light duty vehicles. Even though it has good advantages and there is also a drawbacks for diesel, The fuel in diesel engine is ignited by the heat of the compressed air It results that fuel had no time to fully mix with the air and then it produces hydro carbons, NOX and carbon black emissions more during the combustion process to decrease emissions generally required a catalytic converter this is one of the drawback. Diesel engines are becoming more popular due to its on condition of quality oil fueling and maintenance on the regular base diesel engine can operate up to half-million kilometers without any repair.

The experimental investigations from previous researches on role of emulsion and nanotechnology in alternative fuel for compression ignition engine conclusions says that effect on emulsion fuel on emission parameter of the engine by using diesel water emulsion in the CI engine as a fuel, reduces the overall temperature inside the cylinder. As soon as the atomized fuel is sprayed inside the cylinder during the compression stroke, the water particles get vaporized owing to the high temperature and pressure inside the cylinder. Hence, water takes away some heat from the cylinder for its latent heat requirements to convert into steam. Thus will lower the local high temperature resulting in the reduction of NO_X[1]. The experimental work to investigate performance and emission characteristics of CI engine fuelled with blend of diesel and neem oil methyl ester (B20) along with 250 ppm and 500 ppm TiO2 nanoparticles. The authors reported that brake thermal efficiency increased and brake specific fuel consumption decreased with TiO2 added biodiesel blend compared with pure diesel and biodiesel blend. The emission of CO, HC and smoke reduced, while NO emission slightly increased with TiO2 added biodiesel blend compare pure diesel and biodiesel blend[2].

The examined effects of Performance and emissions of CI engine using diesel and biodiesel blends with nano particles as additive The nano additives act as combustion catalyst which reduce delay period and promote complete combustion when added to base fuel and hence increase efficiency of engine and lower brake specific fuel consumption. The activation energy of nano particles burn off carbon deposits within combustion chamber which lower HC and smoke emission[3].

The evaluated effect of titanium dioxide and calcium carbonate nano additives on the performance and emission characteristics of CI engine Results reveal that use of titanium dioxide nano particles as fuel additives lead to enhanced performance and emission characteristics in comparison to plain fuel and calcium carbonate nano fuel samples[4].

From the Synthesis of Neem Biodiesel experiment test results are 100% bio diesel reduces carbon dioxide emissions by more than 75% compared to petroleum diesel. Using a blend of 20% bio-diesel reduces carbon dioxide emissions by 15%. Biodiesel is an oxygenated fuel, so it contributes to a more complete fuel burn and a greatly improved emissions profile. Hence, it is safe to handle, store, and transport. These are clean burning, renewable, and non-toxic fuels that can be used in neat form or in blends with petroleum derived diesel in diesel engines[5].

2. EXPERIMENTAL PROCEDURE

The investigation is carried out by using neem biodiesel (B100) which is brought from plant and it is in the form of crude oil. By using transesterification process using Sodium hydroxide and ethanol B100 is prepared. The measured properties are mentioned below.

SI No	properties	Neem crude oil	Esterified Neem Biodiesel (B100)	Diesel
1	Density Kg/m^3	965	946	830
2	Kinematic viscosity cst	25.60	10.5	4.0
3	Flash point deg c	220	168	53
4	Calorific value mj/kg	32	38	42
5	Cetane number	32-51	45-51	47

Table 2.1: properties of neem biodiesel

Kinematic viscosity is calculated by using Redwood viscomiter1 and calorific value is measured by using bomb calorimeter.

2.1 Neem Biodiesel

Neem oil is a vegetable oil pressed from fruits and seeds of Neem, an evergreen tree which is widespread to the Indian Subcontinent and in many tropical areas.

2.2 Nano Fluid Additives

Nano fluids are prepared by colloidal suspensions of nano particles in a base fluid. The common base fluids include water, ethylene glycol and oil.

Types of nano fluids

Metallic solids divided in to (Copper, Al, Silver, Gold, Iron and calcium carbonate ($caco_3$))

Non-metallic solids are (silicon, alumina, silicon carbide, carbon nano tubes, Cuo and Tio_2).

2.3 Calcium carbonate nano fluid additive

Calcium carbonate nano particles are synthesized through the precipitation of calcium nitrate and saturated sodium carbonate solution. The chemical composition of caco3 that contains Calcium (40%), carbon (12%) and oxygen (48%). The physical and thermal properties are tabulated.

Melting point	825 °C
density	2.93 g/ml at 25 °C(lit.)
refractive index	1.6583
Storage temp.	Store at RT.
solubility	5 M HCl: 0.1 M at 20 °C, clear, colorless
form	random crystals
color	White-beige to slightly beige-gray
PH	9.5-10.5 (100g/l, H2O, 20°C)(slurry)
Water Solubility	Insoluble

Table2.2 Properties of $caco_3$ nano fluid additive

It is a fluffy powder with a low solubility in water and It decomposes to give carbon dioxide when heated up to 1200K.

2.4 preparations of blends

In this work for preparing of blends I followed a two step method where direct mixing of base fluid with the nano material. In Biodiesel nano fluid or powder is mixed and stirred with rotor of 600rpm which is connected to motor kept in a bowl for proper mixing. In the first blend $Caco_3$ additive (i. e 3gm) is blended with neem biodiesel (B100) of 1litre on mass basis .The second blend contains $caco_3$ nano fluid additive of 5gm is blended with neem biodiesel of 1 liter (5gm/l).

SI No	properties	Neem biodiesel +3gm/l of $Caco_3$	Neem biodiesel +5gm/l of $Caco_3$
1	Density Kg/m^3	938	930
2	Kinematic viscosity cst	8	10.70
3	Flash point deg c	110	92
4	Calorific value mj/kg	40.27	42.01
5	Cetane number	56	66

Table 2.3 Properties of blended fuels

3. EXPERIMENTAL SETUP

The research engine setup has a Standalone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and Engine indicator Rotameters are provided for "cooling water" and "calorimeter water" flow measurement. Engine is directly coupled to an eddy current dynamometer that permits Engine motoring either fully or partially. The Engine and the dynamometer are interfaced to a control panel. By using Sensors which are connected to engine to show readings in a "engine soft" software To obtain performance and combustion characteristics.

Specifications of Engine

Make and model: Kirloskar, TV1.

General details: 4 stroke, CI engine water Cooled direct injection system.

Number of cylinders: one

Orientation: Vertical

Bore and Stroke: 87.5 mm and 110 mm

Swept volume: 661 cc

Compression ratio: 17.5:1

Rated output: 5.2 kW at 1500 rpm

Rated speed: 1500 rpm

Nozzle opening pressure: 180 bar

Fuel injection timing: 23^o CA beforeTDC

Type of combustion chamber: HCC

Fuel: Neem biodiesel and diesel used.

Valve Timing

Intake valve opening: 4.5^0 beforeTDC

Intake valve closing: 35.5^0 afterBDC

Exhaust valve opening: 35.5^0 beforeBDC

Exhaust valve closing: 4.5^0 AfterTDC

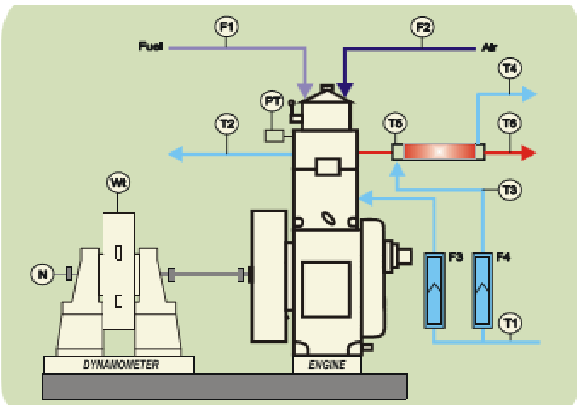

Fig: 3.1. Schematic arrangement

Mars Exhaust five gas analyzer is used to find carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), hydro carbons (HC) and oxides of nitrogen (No_x) from exhaust of the engine.

Fig 3.2 Mars Five Gas Analyzer

3.1 Combustion Chambers Used

Cc is used for proper mixing of fuel and air in short time. Classified in to two categories:

Open Injection (DI) Type: In the DI the total volume of combustion chamber is situated in the main cylinder and the fuel is injected in to this volume.

Indirect Injection (IDI) Type: In this type of combustion chambers the combustion space is divided in to two parts, one part in main cylinder and the other in the cylinder head. The fuel injection occurs generally in to the part of chamber located in the cylinder head.

In this work direct injection chambers are used they are, hemispherical combustion chamber (HCC) and shallow depth combustion chambers (SDCC) .

Hemispherical combustion chamber (HCC):

In HCC the depth to diameter ratio for a cylindrical chamber varied to any design to maintain desired squish in order to provide better performance.

ShallowDepthChamber (SDCC):

In shallow depth chamber the depth of the cavity provided in the piston is small.This chamber is usually adopted for large engines running at low speeds. So the cavity diameter is very large and the squish negligible.

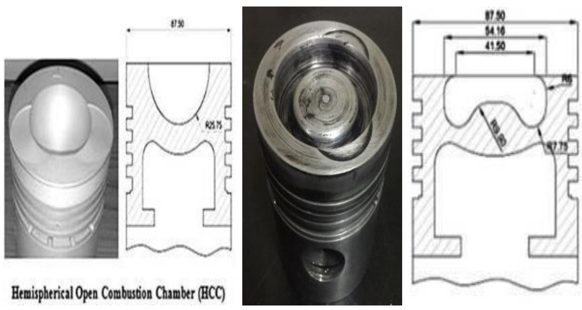

Fig 3.3. Line diagrams of HCC and SDCC

Fig: 3.4 .inside part of a cylinder head when combustion chamber is changing

3.2 Methodology

1. Ensure cooling water circulation for engine and calorimeter.
2. Start the engine and run it at no load for 15-20 minutes.
3. Initial tests are conducted with diesel at 1500rpm speed and by applying variable load conditions, the load on the engine was gradually increased by loading unit, to compare the results of performance, emission, and combustion characteristics of the engine.
4. In the second stage performance, combustion and emission characteristics of diesel engine by using Neem biodiesel (B100) at 0%, 12.5%, 25%, 37.5%, 50%, and 62.5% out of 100% load (i.e16kg) is analyzed and similarly done for all the blends and compared to find a better performance characteristics.

4. RESULTS AND DISCUSSION

The performance parameters like BP, BTE, BSFC, Mechanical efficiency have been evaluated . CO, HC, CO_2, O_2 and NO_X emissions from exhaust are recorded. The above mentioned all neem biodiesel properties are compared with neem biodiesel blends and with diesel properties.

4.1 Brake power Vs % of Load

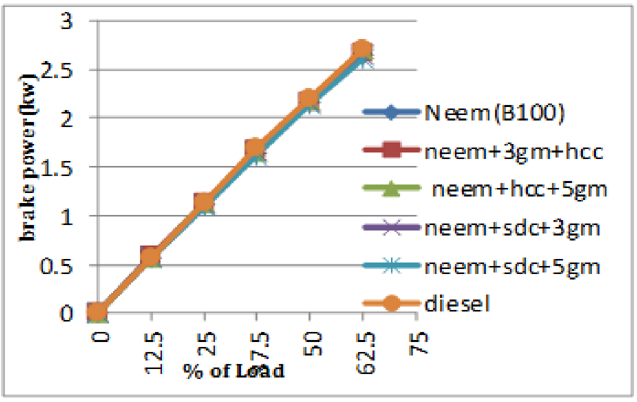

Chart- 4.1: Brake Power Vs % of load

The graph is drawn between BP vs load (%) that is full load/max load 16kg is taken as 100% load and simultaneously the % are divided for 0, 2,4,6,8 and 10kg of load. Brake power is almost same for all the fuels.

4.2 Break Specific Fuel consumption Vs % of load

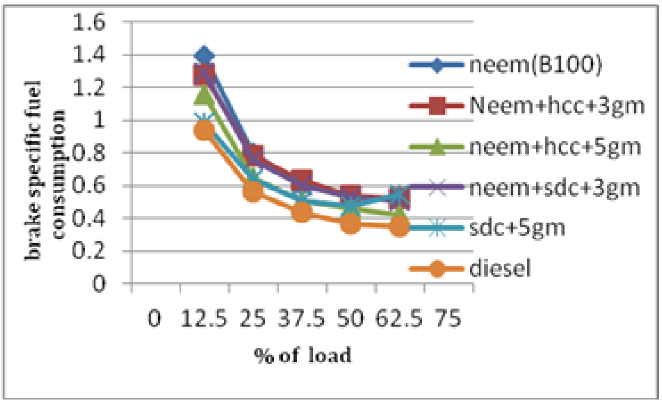

Chart- 4.2: BSFC Vs % of load

From the graph the specific fuel consumption is known that At higher load points the brake thermal efficiency is increased and brake specific fuel consumption decreased. BSFC is more for tcc+neem+5gm cac03 at 12% of load and its go on decreasing at higher % of loads. The BSFC is less for HCC+5gm and sdcc+3gm is preferable other than diesel fuel.

4.3 Brake Thermal Efficiency (η_{bth}) Vs % of load

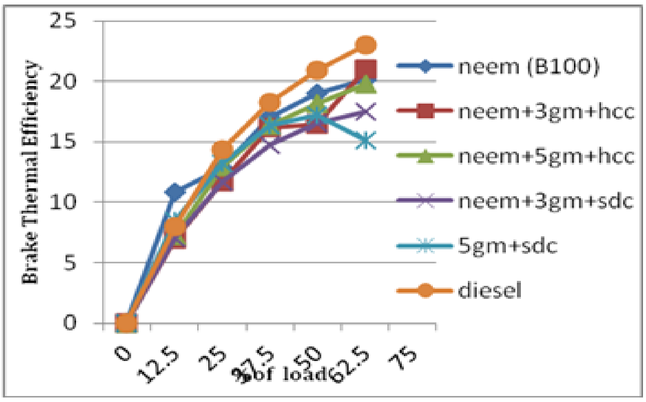

Chart-4.3: BTE Vs % of load

It is found that BTE increases with the increase in load for all the fuels. BTE more for 3gm+hcc and less for the SDCC used fuel at 62.5% high load.

4.4 Mechanical Efficiency (η_m) Vs % of Load

It is used to find the effectiveness of an diesel engine in transforming the input energy to the output energy, to an IC engine, it is the ratio of BP to IP.

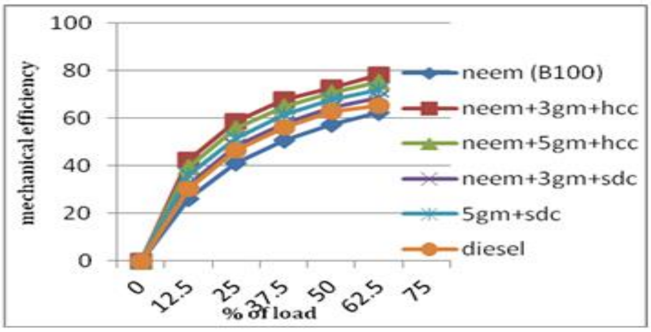

Chart- 4.4: Mech. Efficiency Vs %of load

Mechanical efficiency is equal for 3gm+neem+hcc fuel and sdcc+5gm+neem fuel so in order to require high efficiency at higher loads this two are preferable.

4.5 Oxides of Nitrogen Vs % of load

NO_x emissions increases in biodiesel operation due to the reactive nature of biodiesel molecule at higher temperature and oxygen present in its structure will be low.

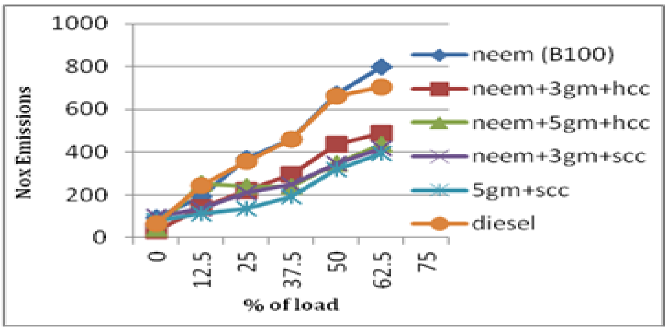

Chart- 4.5: Nox Emission Vs % of load

By adding calcium carbonate, there is reduction in No_x emission. This is because calcium carbonate contains 48% of oxygen acts as an oxygen buffer. To decrease No_x additives are used.

4.6 CO Emissions Vs % of load

Co emissions will increase when there is a insufficient oxygen and incomplete combustion process occurred.

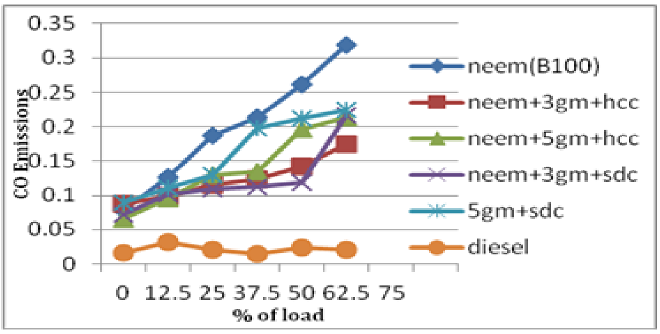

Chart- 4.6: CO Emissions Vs % of load

If un burnt particles are less then co emissions will be less because if un burnt emissions are less then complete combustion will take place. co emissions are less for neem+3gm of $caco_3$ with HCC chamber.

4.7 Carbon Dioxide Emission Vs % of load

Due to the decrease in break thermal efficiency energy released is less in turn there is a reduction in CO_2. It is found that The lower percentage of biodiesel blends emits very low amount of CO2 in comparison with diesel.

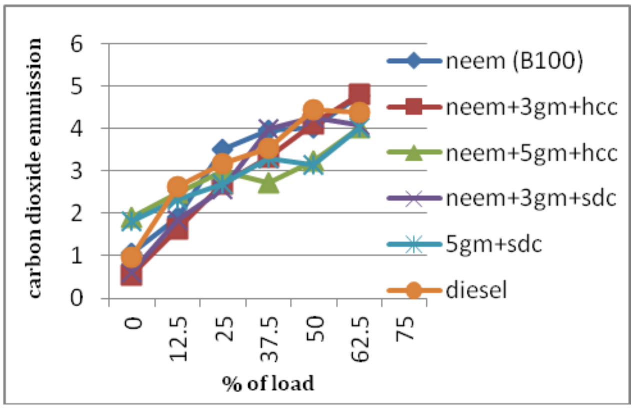

Chart-4.7: Co_2 Emission Vs % of load

4.8 Unburnt HC Emission Vs % of load

It is formed due to un burnt hydrogen and carbons in fuels. In shallow depth chamber the combustion taken place completely and there is very low un burnt emissions for fuels with shallow depth chamber.

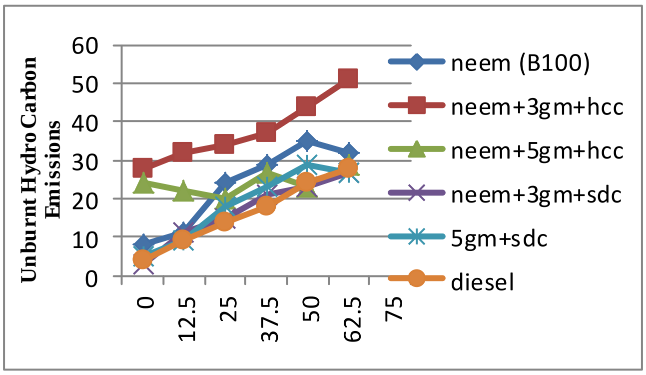

Chart-4.8: Unburnt HC Emission Vs % of load

5. CONCLUSION

In this work the performance and combustion characteristics are studied by Using two proportions that are added to neem biodiesel with two combustion chambers. By increasing % of loads the readings are noted and observed that

- Shallow depth combustion chamber resulted in higher performance. Other than diesel.
- No_x emissions are decreased by using nano additives but No_x emissions are slightly more for fuels with SDCC chamber and less for HCC chamber.
- Brake thermal efficiency by using SDCC is 10% less when it is compared with other fuels. SFC is almost same for all neem biodiesel blends when load is increasing consumption is more for shallow depth chamber.
- Mechanical efficiency for neem biodiesel (B100) is low due to the reason of mechanical losses which occur may be due to friction, or due to power absorbed.
- To achieve complete combustion process to decrease the un burnt HC emissions the SDCC is more suitable the emissions are same as that of diesel fuel. By using different combustion chambers there is a reduction in emissions, high performances are achieved from neem biodiesel with additive blends can be preferable as a replacement of diesel fuel.

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