Effects of piston and cylinder swirl generation on the performance of ceiba pentandra and nigella sativa B20 biodiesel blended diesel engine operation

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Abstract. In order to improve the combustion of two B20-based Ceiba Penandra (CPNTOME B20) and Nigella Sativa (NIZSAOME B20) selected for the analysis, experimental investigations into a modified diesel engine have been conducted with artificially induced swirl techniques implemented on both the piston and the head of the cylinder. B20 Biodiesels Used to decrease dependence on fossil-based fuels and there by address the alarmsin emission levels in the atmosphere as biodiesels are renewable and are carbon neutral candidates. Growing number of piston grooves and number of cylinder head grooves and bridges increase engine output in terms of higher thermal break efficiency (BTE), lower hydrocarbons (HC), carbon monoxide (CO), smoke emissions while CPNTOME B20 showed higher performance while NOx increased from the two B20 blends.

Keywords: Swirl techniques, B20 blends, Ceiba Pentandra, Nigella Sativa, Smoke, NOx emissions.
1. Introduction

Due to increased demand for fuels, petroleum resources as a commodity are declining in their strength day by day and leading to new challenges for science and technology. Bioenergy is commercialized to combat the issue of petroleum scare and its effect on the environment. Several research studies have been carried out, pointing out that biodiesel helps to minimize greenhouse gas emissions, foster stable rural growth and increase economic distribution. [1].

Currently, alternative energy sources for vehicles are of considerable interest and are the result of continuous concern about the environmental impact of transport, particularly in the emission of greenhouse gas and toxic components, due to the constant use of primary energy sources, which are restricted, emissions are growing and the fuel industry will have to adjust its products to meet this challenge. Alternative fuels are those that are characterized by their high heating value and, relative to fossil fuels, their use results in lower emissions. There are already many fuels in use from previous study work on the use of alternative fuels. [2].

K.A.Abed et.al[3] Exhaust emissions such as CO, CO2, NOx and HC and smoke using biodiesel from various feedstocks and mixed with diesel oil in various B10, B20 proportions were examined and CO2 emissions Compared to diesel fuel derived from biodiesel mixtures B10 and B20 from waste cooking oil, this was found to be higher. For both B10 and B20 biodiesel blends, NOx emissions from both the B10 and B20 biodiesel blends are higher than diesel fuel emissions.

By using 100% bio diesel and increasing the mixture of biodiesel and diesel as a fuel in diesel engines with varying compression ratios, Vipin Raghuvansi et.al[4] conducted experimental work. Three compression ratio experiments were conducted, i.e.

14, 16 and 18 use diesel biodiesel mixes, e.g. B10, B20, B30,B40, B60 or plain biodiesel load differently than diesel fuel engines, from zero to full load. . It is observed that out of all test fuel blends, the B20 blend has improved performance and reduces emissions of CO, CO2, and unburned HC and nitrogen NOx oxides compared to other test fuels. .

An experiment on biodiesel developed from Juliflora seeds was performed by M.A.Ashokan et.al[5] via a transesterification process that yields 80 percent methyl easter Juliflra. Compared with those of diesel (D100), Compared to diesel (D100),Data from the experiments were released for fuel mixtures (B20, B30, B40, and B100). The results of the study show that the B20 blend's efficiency and combustion properties are almost in line with those of the diesel engine. For blends of B20 and B30 at
maximum charge, BSFC was similar to the diesel engine. It is assumed that the B20 blend is the most suitable blend compared to those of the other.

Nandeesh M et.al [6] conducted an experimental study using Maintaining injection time from 190 to 270 BTDC maintaining steady injection pressure of IOP, biodiesel milk oil methyl esther B20 (DSOME B20) study. The result was showing that Increased emissions of BTE, lower haze, HC, CO when NOx.

The fuel characteristics of biodiesel from Ceiba pentandra and Nigella sativa non-edible oils have been investigated by T.M Younus Khan et.al [7] via their research work through the acid esterification and alkali transesterification processes to determine that the biodiesel produced and its feedstock conform to the standard properties of ASTM6751. And they also concluded that when compared to N.Sativa, C.pentadra biodiesel has greater Quality of calorific, flash, and viscosity. N.Sativa has strong oxidation stability as opposed to C.pentandra.

Pandian Shivakumar et.al[8] The synthesis of biodiesel in non-edible Ceiba Pentadra oil has been studied. The experiment conducted two-stage acid-base transesterification. . Biodiesel conversion 99.5 percent has been found under optimum conditions of 1.0 wt KOH and 6:1 methanol oil molar ratio at a temperature of 650C for a reaction time of 45 minutes. Kinetic tests are conducted at different temperatures and the physical and chemical properties of C.Pentandra have been found to comply with the limits prescribed by ASTM D6751 specifications.

C.Pentadra seed oil maintained constant feedstock in Indonesia ( N.A.Handayani et.al 2013), C.Pentadra seed oil can be produced by using naturally potassium hydroxide catalyst, research is carried out at two levels with 3 independent variable temperature, reaction time and oil-to-molar ratio according to the findings biodiesel meets all the standards by SNI 04-7182-2006, molar ratio methanol to oil is the most influence parameter[9]. Using swirl augmentation techniques by modifying the surface of piston and cylinder head optimises the BTE and major pollution reductions like HC, CO and NOx ( N.R.Banapurmath et.al 2013) the test was conducted to study the Compression results, the strategies of swirl raise and the incorporation of ethanol to the combustion into a double fuel engine of Natural gas compressed combined fog oil methyl easter. At injection timing 270 BTDC and compression ratio of 17.5 the output is improved [10].

V.S.Yaliwal et al. studied the Combustion Chamber Influence The efficiency and emission properties geometry and nozzle effect . The test were conducted using 3,4,5 nozzles with orifice diameter of 0.2,0.25,0.3mm respectively. The four-stroke water cooled engine, DI controlled in HOME and maker petrol, was used as hemispherical and re-entrant configurations for a test in dual fuel mode, resulting in a maximum output of 4hole 0.25mm nozzle orifice using a re-entrant at 230 bar injection pressure [11].

Vinay kumar (2017) Carrie d an experiment by considering two piston engine shapes Toroids chambers with tangential cuts on the piston crown circumference and the hemispheric combustion chamber with circular arc on the piston crown circumference of the regular hemispherical piston form combustion chamber, on comparing results keeping constant engine speed, compression ratio due to high swirling induction the modified piston shows better performance and huge reduction in the combustion and emission characteristics except NOx emissions[12].

M.R.Indudhar et.al experimented by using viscous Bio-diesel (HOME) with injectors 3 to 5 in the manufacture of a modified diesel engine, masking angle 300-900, 3-9 piston grooves 1-3 bridges and 2-4 cylinder head grooves. The findings show that low emissions in HC, CO or slightly higher NOx emissions were increased in conduction when the number of injectors was increased , Masking angle, piston grooves and cylindrical head are raised to some stages, above which output is decreased. Better results were obtained for last 3 modifications [13].

From the exhaustive literature survey on the utilization of Ceiba Pentandra and Nigella Sativa B20 blends with swirl induction techniques has not been investigated in detail [13].

2. The objectives
   • Characterize B20 blends of Ceiba Pentandra and Nigella Sativa and compare their properties with diesel to check their feasibility compatible fuels.
• Develop suitable swirl techniques to improving diesel efficiency engines powered with B20 blends respectively.

• Compare the performance with and without swirl enhancement techniques.

3. Materials methods

A non-edible, resistant plant widely referred to as capok fibre, Ceiba pentandra. The seeds of C. For each fruit, Pentands is brownish and weighs 25-28 percent, with a normal annual oil return of 1280 kg/ha. It has been suggested as a feedstock appropriate for the making of biodiesel. Nigella sativa, which behooves the With more than 35% oil content, the botanical family Ranunculaceae, is commonly referred to as black seed or black cumin. Born in south-west Asia, it is also grown in various parts of the country.

Chemical reactions, including esterification and transesterification, have created biodiesel from crude oil. By transforming them into methyl esters, the transesterification process is used to decrease crude oils' viscosity. The acid content of both crude oils is high, so both natural oils were initially sterryfied or acid-catalyzed. In the method of esterification, crude oil was blended with methanol at a volume ratio of 2:1. The combination of crude oil and methanol was added to 98 percent of condensed sulphuric acid (1 percent v/v oil). However, because of its higher acid value relative to its counterpart C, 37 percent of concentrated hydrochloric acid (1 per cent, v/v, oil) was used in the manufacture of biodiesel from N.sativa. The oil from Pentander. The mixture of crude oil, methanol and the corresponding catalysts was refluxed at a stirrer speed of approximately 700 rpm with steady boiling in the reactor at 600C for 3 hours. The reaction halted after 3 hours. There were two layers of the mixture obtained, the upper layer of methanol and vinegar and the lower layer of esterified crude.

With the aid of the separation funnel, the esterified oil was separated from methanol and other impurities. To remove traces of moisture content and residual alcohol, the esterified oil was added to the rotary evaporator. Reaction conditions for alkaline catalysis or transesterification is similar to those for esterification. In this process, the esterified oil was mixed with methanol at a volume ratio of 4:1 in the reactor. One percent of potassium hydroxide by weight was added to the mixture. The reaction lasted 2 hours at a temperature of 600C and a stirring speed of 700 rpm. With the aid of the separating nozzle, after 2 hours of reaction, biodiesel's upper layer was removed from the lower layer of methanol, plus other impurities. Post-treatment processes followed this. Hot (60oC) distilled water washed the transesterified oil twice. Clean biodiesel was then placed into a rotary evaporator and the same procedure was used to evaporate biodiesel moisture and excess methanol that was previously applied to esterified oil.

The biofuels to be tested were blended with diesel in varying ratios using a homogenizer system. The homogenizer was attached to a clamp on a vertical stand to change the height of the homogenizer. The two fuels were mixed by turning on the homogenizer plug in the proper proportions, i.e., biodiesel and diesel. 10 percent, 20 percent, 40 percent, 60 percent and 80 percent biodiesel is blended with the equivalent amount of diesel. As a result, B10 was assigned 10 percent biodiesel and 90 percent diesel by volume. Likewise, others were classified as B20, B40, B60, and B80. Figure 1(a), 1(b), and 1(c) shows the modified piston with 3 grooves, 6 grooves and 9 grooves respectively.

![Figure 1](image-url)
Table 1 shows the fuel properties of Diesel and fuel properties of Ceiba Pentandra, Nigella Sativa and their blends of B100 and B20.

| Parameters                  | Diesel | B100 | B20 |
|-----------------------------|--------|------|-----|
| Density, Kg/m³              | 820    | 0.8844 | 0.8861 | 0.8408 | 0.841 |
| Viscosity (At 40⁰ c), mm²/sec | 2.87   | 4.4180 | 4.5026 | 3.7089 | 3.7016 |
| Calorific Value, KJ/Kg      | 45,500 | 40,064 | 39,967 | 44,155 | 44,131 |
| Cetane Number               | 48.5   | --    | --    | --     | --     |

4. RESULTS AND DISCUSSION

Experimental investigations are done to study the influence of piston grooves & cylinder grooves on the performance of CPNTOME B20 and NIZESAOME B20 fuelled modified diesel engine. The engine speed was maintained constant at 1500 rpm, CR=17.5, injection timing 230 BTDC, injection opening pressure 240 bar.

4.1 Effect of Piston Grooves on B20 Power Diesel Engine:

From figure 2 Brake thermal efficiency (BTE) of all fuels increases with increase in brake power as more fuels gets injected inside the engine cylinder. BTE of both B20 biodiesel blends showed lower magnitude due to their comparatively lower calorific value and higher viscosity. Between the two B20 biodiesel blends CPNTOME B20 showed higher BTE due to improved fuel properties.

It may be noted that as the number of piston grooves were increased from 3 to 6, both B20 blends showed enhanced BTE and this could be due to improved uniform Shape of air-fuel mixture due to swirl-induced. An increase more in the piston grooves from 6 to 9 showed a drop in BTE.

4.2 Emissions

4.2.1 Smoke Opacity

Smoke opacity variation (Figure 3) showed increasing trends with B.P., as the quantity of fuel injected increases with an increase in the B.P. Smoke opacity of both B20 biodiesel blends showed
higher magnitudes due to their comparatively more massive molecular structure due to their comparatively higher viscosity and lower volatility. Between the two B20 biodiesel blends, CPNTOME B20 showed lower smoke emissions due to improved fuel properties.

It may be noted that as the number of piston grooves were increased from 3 to 6, both B20 blends exhibited decreased smoke emissions and this could be attributed to uniform air-fuel mixture formation associated with swirl generation. There was no much further improvement notices when piston grooves were increased further from 6 to 9.

![Figure 3. Variation of B.P on smoke opacity with Piston Grooves](image1)

### 4.2.2 UBHC Emissions: HC Emission:

Figure 4 and 5 shows variation of HC and CO emissions and as seen for all the fuels both HC and CO emissions and as seen for all the fuels both HC and CO increased with increase in B.P., as more fuel gets injected inside the engine cylinder. HC and CO emissions of B20 blends showed higher magnitude as compared to diesel. The wall wetting phenomenon observed with B20 biodiesel blends showed higher HC emissions. However, as the piston grooves were increased from 3 to 6 improved air-fuel mixture resulting inside the engine cylinder due to swirl induced. But further increase in the piston grooves to 9 showed no improvement. Similar trends were obtained with CO emission behavior. CO represents incomplete combustion prevailing inside engine cylinder. It showed improved trends with increased number of piston grooves till 6 grooves beyond which no improvement observed.

B20 blends CPOME showed lower UBHC emissions compared to NIZEASA B20 due to difference in the fuel properties. Same engine operating conditions with B20 blends for fixed number of piston grooves showed noticeable changes in BTE and emission behavior.

![Figure 4 Variation of B.P. on HC Emission with piston grooves](image2)
Figure 5 Variation of B.P. on CO Emission with piston grooves

4.2.3 NOx Emissions
Variation of NOx emissions with B.P. for B20 blends considered in figure 6, shows that both blends showed lower NOx emissions compared to diesel operation. The reasons for these trends are that higher BTE obtained with diesel compared to B20 blends due to higher heat release rates in terms of higher premixed combustion phase. However, as the number of grooves on piston increased from 3 to 6, higher swirl resulting in to enhanced air-fuel mixture formation enhances the in-cylinder temperature and there by NOx increased for both B20 blends. CPNTOME B20 blend showed comparatively higher NOx due to its improved fuel properties.

Figure 6 Variation of B.P. on NOx Emission with piston grooves

4.3 Combustion Parameters:
Figure 7 (a-c) shows the variation of combustion parameters like PP, ID and CD respectively [ PP – Peak Pressure, ID-Ignition delay, and CD-Combustion duration] B20 biodiesel blends showed poor combustion characteristics like lower PP, higher ID, and CD respectively when compared to diesel fuel operation. However as the number grooves increased from 3 to 6, improvement in higher PP, lower ID and CD were obtained due to swirl generated inside the engine cylinder ensuring improved air-fuel mixture for motion. Beyond 6, number of grooves showed no improvement.

CPNTOME B20 was considered in the study due to its comparatively better performance to NIZESAOME B20.
Figure 7 Variation of combustion parameters (a) Variation of Peak Pressure with BP for different piston grooves, (b) Variation of Ignition Delay with BP for different piston grooves (c) Variation of Combustion Duration with BP for different piston grooves

5. Conclusions

Experimental testing was performed to study the effects of piston grooves on the performance of two B20 biodiesel blends. From the study, the following conclusion were made.

- CPNTOME B20 and NIZSAOME B20 biodiesel engine operation was smooth. However, the performance of biodiesel operation was not encouraging.
- Between the two B20 biodiesel blends CPNTOME B20 showed comparatively enhanced engine performance.
- Increasing the number of piston grooves from 3 to 6 on piston resulted in higher BTE, lower smoke emissions, HC, CO and higher PP, lower ID and lower CD respectively.
- Hence it can be concluded that 6 number of grooves on piston with CPNTOME B20 biodiesel fuelled engine can provide satisfactory results.

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