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Experimental Investigation on the Performance of Cotton Seed Biofuel Blended with Nanoparticles on a Variable Compression Ratio Diesel Engine

P. D. Kabudke[1], Y. R. Kharde[2], S. N. Shelke[3]

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Abstract: The rapid increase in worldwide population and changing living style of human are the reasons behind energy crisis. Fossil fuel is a leading factor involved for atmospheric pollutants. However, biofuel play a significant role in increasing engine efficiency and reducing emissions. This research works contributes to enhance the performance of diesel engine. The cotton seed oil is converted into biofuel through transesterification process. Since, raw cotton seed oil, under the category of edible as well as non-edible vegetable oils. The viscosity and calorific value are the distinct properties of biodiesel and diesel fuel. The fuel's properties, and conducting experiments with compression ratios of 18, 20, and 22. Five constant loads of 0 kilograms, 3 kilograms, 6 kilograms, 9 kilograms, and 12 kilograms are maintained while the engine rotated at a constant speed of 1500 revolutions per minute (rpm) with the injection timing set to 23.5 degrees before the top dead center (TDC) variable. Initial testing was conducted with 18, 20, and 22 compression ratios for CB20, CB30, CB40, and CB100. The BSFC value was 0.34 kg per kilowatt-hour for a mixture of CB20, CR22, and greater BTE. CB20 biofuel with a compression ratio of 22 shows the lowest levels of carbon monoxide, hydrocarbons, and nitrogen oxides

Keywords: *Biodiesel, Cotton seed oil, variable compression ratio, blends.*

Introduction:

Biodiesel is an emerging field globally and locally. The Government of India greatly encouraged the use of biofuels in the 2000s. The use of biodiesel as a renewable, sustainable and alternative fuel has been increased over the last 10 years to study engine efficiency and emission effects. A comparative study of the effects of biodiesel engines, including efficiency, energy, durability and pollution, regulated and unregulated emissions, and associated impact factors. The use of biodiesel significantly reduces emissions of PM, HC and CO, as well as lowers energy, increases fuel consumption and increases NOx emissions without any or all changes to conventional diesel engines and thus helping reduce carbon reserves Biofuels have better properties compared to diesel fuels such as sustainable, non-toxic, environmentally safe, environmentally benign, and sulfur-free, biodegradable [6-8]. The results (methyl esters, fatty acids, alcohol, etc.) were good in terms of cutting down on toxic exhaust fumes. [9]. Developing countries depend a lot on fossil fuels, especially for their industries and transportation. Due to a lack of fossil fuels, rising crude oil prices around the world, and environmental concerns, green energy sources are becoming more and more important today [11, 12]. Vegetable oils have some of the same qualities as diesel fuel and are better than fossil fuels in many ways, such as being safe for the environment, non-toxic, recyclable, and helping to keep the environment in balance [13]. Their cetane number and pressure at vaporization are almost the same as diesel. Biodiesel has extra oxygen atoms in its chemical structure. This lets it add oxygen to the fuel, which helps it burn better. Even though they have a lot of pros, they also have some cons, like a high .viscosity, bad cold flow, and a lower heating value [14]. One new way to improve how fuel burns and how it works is to add fuel additives. In the last ten years, alcohol-based additives like ethanol, butanol, heptanol, and diethyl ether have been used more and more in biodiesel fuel mixes [15]. Alcohol-based chemicals increase the amount of

1Research scholar, Research Centre, Mechanical Engineering Department, Amrutvahini College of Engineering Sangamner, Ahmednagar, Maharashtra, India.

2,3Professor, Mechanical Engineering department Pravara Rural Engineering College, Loni, Ahmednagar, Maharashtra, India

oxygen in the combustion.chamber to cut down on emissions. However, because a leaner mixture is made, the calorific value goes down. High auto-ignition temperatures and less effective oil wear down the engine and make it less effective. So, the experts looked into how micro and nano particle additives might work. The micro particle additives helped improve the engine's performance, but the clumping kept happening. Nanotechnology has been used in many areas of industry, such as building, agriculture, medical science, biotechnology, transportation, etc. The thermo physical features of the nanoparticle additives were better, and they mixed easily with any base fluid [16–18].The commercialization of bioenergy has provided an effective way to combat the problem of petroleum scarcity and its impact on the environment. Biodiesel is an alternative fuel to diesel and is renewable, biodegradable and oxygenated. Although a number of studies have shown that greenhouse gases can help reduce emissions, promote sustainable rural development, and improve income distribution, there are some drawbacks to using it. Lack of awareness about the effects of biodiesel on diesel engines is the primary reason.The reduction in engine power as well as the increase in fuel consumption due to biodiesel is not as expected. The findings of the initial research have been kept in the minds of many people, i.e. biodiesel is more likely to be oxidized which can lead to insoluble gums and sludge which can plug the fuel filter and thus affect the durability of the engine.

Nomenclature

CB Pure Cottonseed biofuel
CB100 100%Cotton seed biofuel
CB 20 20% CB + 80% diesel
CB30 30% CB + 70% diesel
CB40 40% CB + 60% diesel
CB30 30% CB + 70% diesel
50 ppm Parts per Million
DE Diesel Engine
BP Brake Power
BTE Brake thermal efficiency
BSFC Brake specific fuel consumption
CO Carbon monoxide
CO2 Carbon dioxide
VCRDE Variable compression ratio Diesel engine
HC Hydrocarbon
NOx Nitrogen oxides (PPM)
O2 Oxygen.

Material and Methodology:

Material

Large amounts of diesel and biofuels were employed as liquid fuels in this experiment; cotton seed oil was used to produce biodiesel, and both were purchased locally. Potassium Hydroxide (KOH) and Analytical Quality Methanol (Merck, 99.5%) were supplied by Apex Innovation Pvt. Ltd. in India. Table 1, provided by Nikhil Analysis and Research Pvt. Ltd., displays the fatty acid composition of cotton seed oil. Biodiesel product is used to analyze the gas chromatograph. Sangli Ltd.

Method:

Using diesel blends CB100, CB20, CB30, and CB40, an experiment was conducted on a single-cylinder, variable compression ratio (VCR) diesel engine (CR18, CR20, and CR22) with a power output of 3.5 kW at 1500 revolutions per minute (constant speed) with variable loads (0%, 25%, 75%, and 100%) in order to achieve BSFC, BTE.

Fig. 1: Transesterification process experimental setup.

Table 1. Cotton seed oil fatty acid composition.

Fatty Acid name	Structure	Weight %
Myristic Acid	C14:0	00.532
Palmitic Acid	C16:0	10.28
Stearic Acid	C18:0	03.63
Oleic Acid	C18:1	32.83
Linoleic Acid	C18:2	39.28

Experimental Setup:

With all the required tools, including a computer-interface diesel engine manufactured by Kirloskar, we have experimented with a single-cylinder, water-cooled, variable compression ratio dynamometer connected to AD current. The table displays comprehensive information about the VCR diesel engine. System EngineSoft LV collects, stores, and analyzes data from trials using a variety of measuring sensors using "engine performance analysis software with computerized data editing systems."

Additionally, we experimented with variable compression ratios between 18 and 22 with varying load values. The AD current type dynamometer, strain gauge type load cell, and loading unit make up the load measuring apparatus utilized in this experiment. Measuring the load placed on the engine with a load cell.

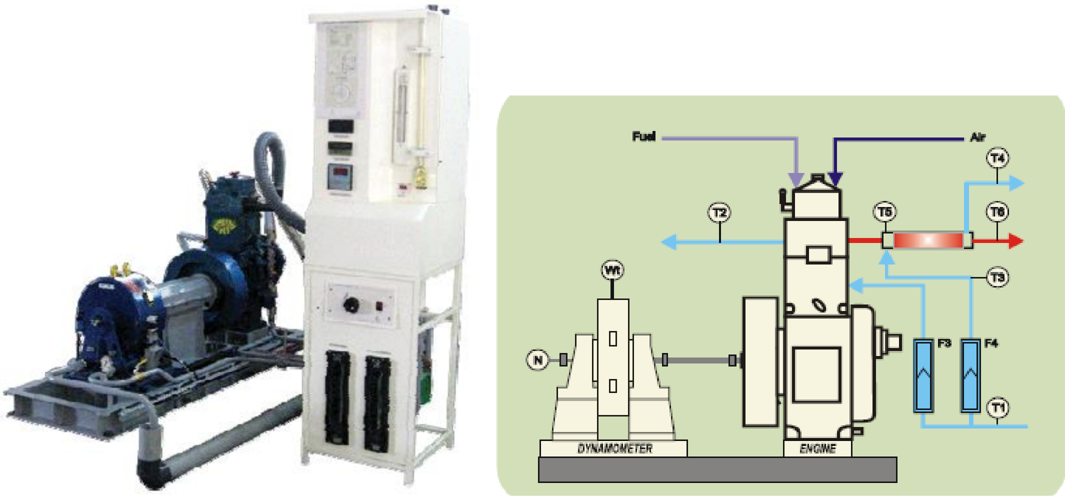

Fig. 2 Schematic representation of VCR test rig.

Table 2. Engine Specification.

Sr.No.	Parameter	Specification
1	Product	VCR engine test setup 1 cylinder, 4 stroke, Diesel.
2	Product code	234.
3	Engine	Make Kirloskar, Type 1 cylinder, 4 stroke, Diesel, water cooled, power 3.5kw @1500rm, stroke 110mm, bore 87.5mm.661 cc, CR 17.5, Modified to VCR engine CR range 12 to 23 .
4	Dynamometer	Type eddy current, water cooled, with loading unit.
5	Propeller shaft	With universal joints.
6	Air box	M S fabricated with orifice meter and manometer
7	Fuel tank	Capacity 15 lit with glass fuel metering column
8	Calorimeter	Type pipe in pipe.
9	Piezo sensor	Range 5000 PSI, with low noise cable.
10	Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
11	Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
12	Piezo powering unit	Make –Cuadra, Model AX-409.
13	Digital Milivoltmeter	Range 0-200mV, panel mounted.
14	Temperature sensor	Type RTD, PT100 and thermocouple, Type K.
15	Temperature Transmitter	Type two wire, input RTD PT100, Range 0-100 ^{0}C, output 4-20 mA and type two wire, input thermocouple, range 0-1200 ^{0}C, output 4-20 mA .
16	Load indicator	Digital, Range 0-50 kg, Supply 230VAC.
17	Load sensor	Load cell, type strain gauge, range 0-50 kg.
18	Fuel flow transmitter	Dp transmitter, range 0-500 mm WC.
19	Software	"EnginesoftLV" Engine performance analysis software.
20	Rota meter	Engine cooling 40-400 LPH; Calorimeter 25-250LPH.
21	Pump	Type Mon block.

22	Overall dimensions	W 2000 × D 2500 × H 1500mm.
23	Optional	Computerized Diesel injection pressure measurement.
24	Shipping details	Gross volume 2.46m^3, Gross weight 808kg.

Table 3. Properties of fuel

Fuel properties	**Standard**	**Diesel**	**CB100**	**CB20**	**CB20 +50ppm**
Density @25 0C (gm/cm3)	ASTM D287	0.83	0.881	0.8402	0.831
Specific Gravity	ASTM D287	0.83	0.881	0.8402	0.840
Gross Calorific Value Cal/gm	ASTMD 4809	42965	40162	42404	10190
Flash Point 0C	ASTMD 93-58T	70	154	86.8	98.6
Fire Point 0C	ASTMD 93-58T	76	165	93.8	92.5
Cloud Point 0C	ASTM-D 97	-6	0	-4.8	-4.7
Pour Point 0C	ASTM-D 97	-10	-4	-8.8	-8.7
Kinematic Viscosity @40 0C cst	ASTMD 445	2.8	6.43	3.526	4.020
FFA %	> 2.5	-	0.53	-	50

Result & Discussions:

The experiments mentioned above allow for a few conclusions to be made:

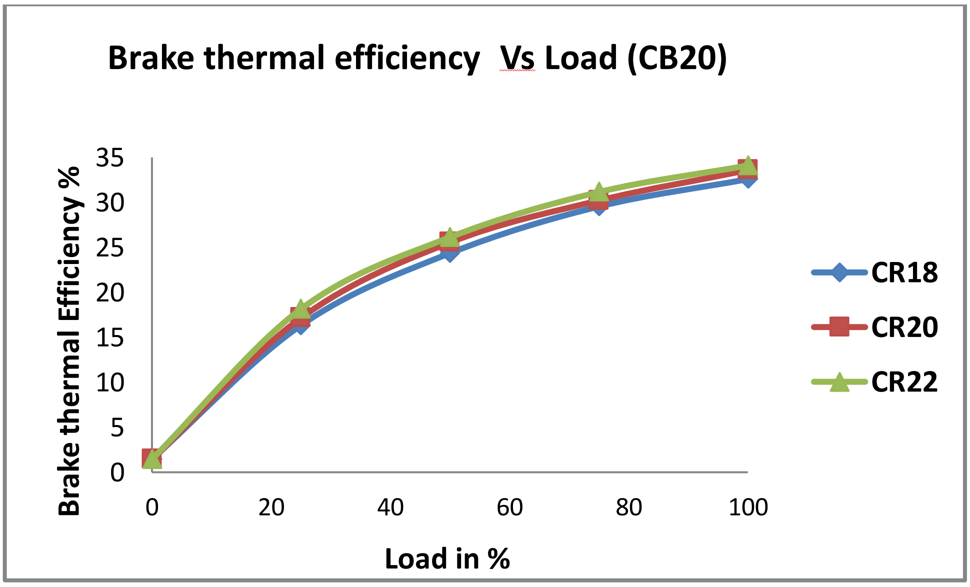

Fig 3.The effect percentage of blends on brake thermal efficiency at same CR 18.

The effect of the biodiesel mixture percentage on performance was investigated under various loads. The graph makes these consequences quite evident. By calculating the ratio of brake power to engine heat from fuel combustion, brake thermal efficiency was determined. Because of the reduced fuel energy, the brakes' thermal efficiency was 1–4% lower than that of pure diesel. The graph curve indicates that load efficiency rises as it does. Brake thermal efficiency was shown to be somewhat poorer when the quantity of biofuel mixture in diesel was increased.

Engine Performance

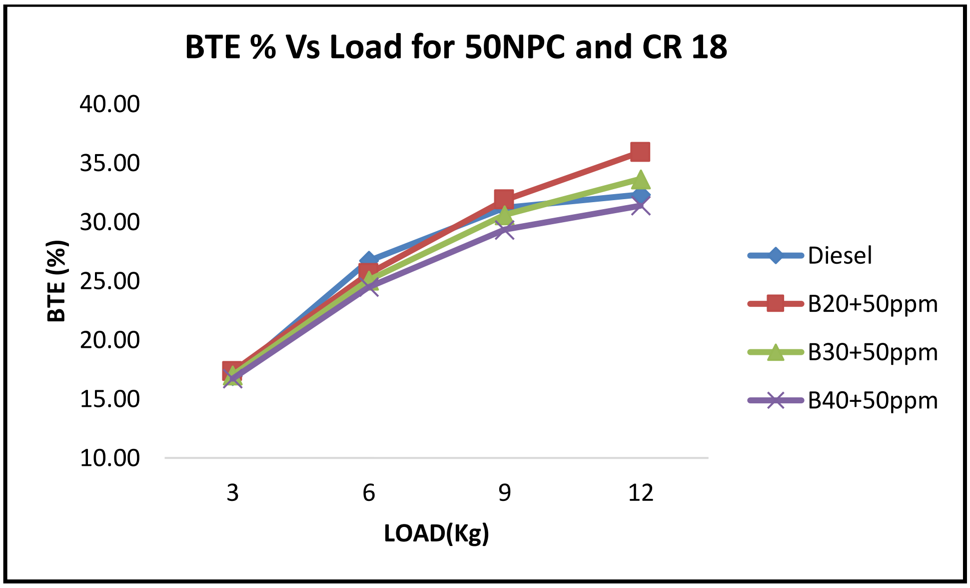

Fig. 4 Effect of brake thermal efficiency w.r.t. Load for CR 18, 20 & 22 (CB40).

The BTE goes up as the load goes up for all fuels because the pick temperature goes up. [18] As compared with diesel, blends show higher BTE at all loads or above 50 % loads. This is due to higher oxygen contents (in cerium oxide nanoparticles and 10% to 11% in cottonseed) in fuel blends. At full load, the BD2 blend shows higher values of BTE, which are 38.09% from the figures 4 having compression ratios 18, 20 and 22 the effect of load on brake thermal efficiency for NPC with biodiesel blend can be made.

Effect of CR

The experimentation is carried out at different value of compression ratio from 18 to 22 it was observed that the brake thermal efficiency is increases around 2 to 6 percentage for different biodiesel blend. The increase in brake thermal efficiency occurs because of reduction in heat loss and increase in power with increase in load. Theoretically well known that as the increase in compression ratio result in better proper mixing of air and fuel during the working stroke of engine and increase in cylinder pressure this leads to reduce in delay period of combustion.

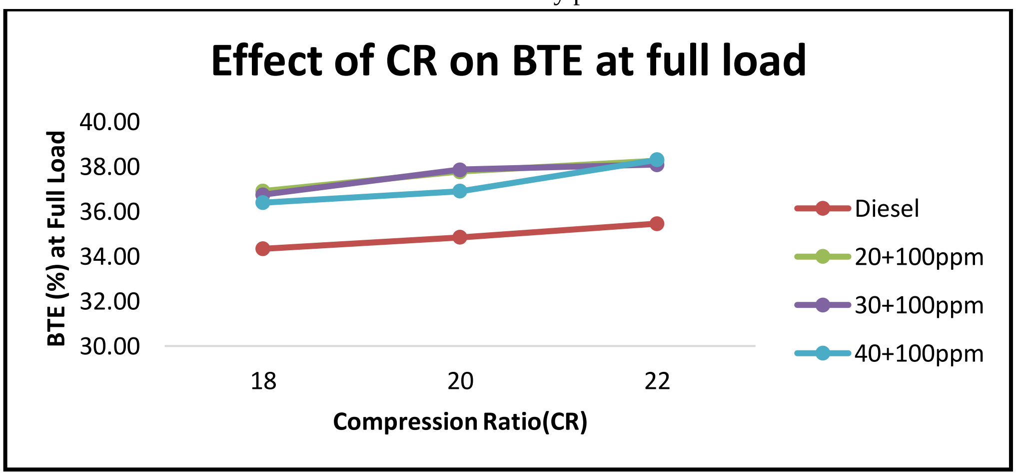

Fig. 5 Indicated mean effective pressure vs compression ratio.

The BTE is higher at CR 22 due to a rise in cylinder pressure temperature, and NHR increases with nanoparticle concentration.

As increase in compression ratio bettor combustion efficiency and combustion occurs at top dead centre peak pressure in cylinder increases at the end indicated mean effective pressure goes on increase. By experimentally investigated that indicated mean effective pressure is higher at higher compression ratio at 50 percent to 100 percent load.

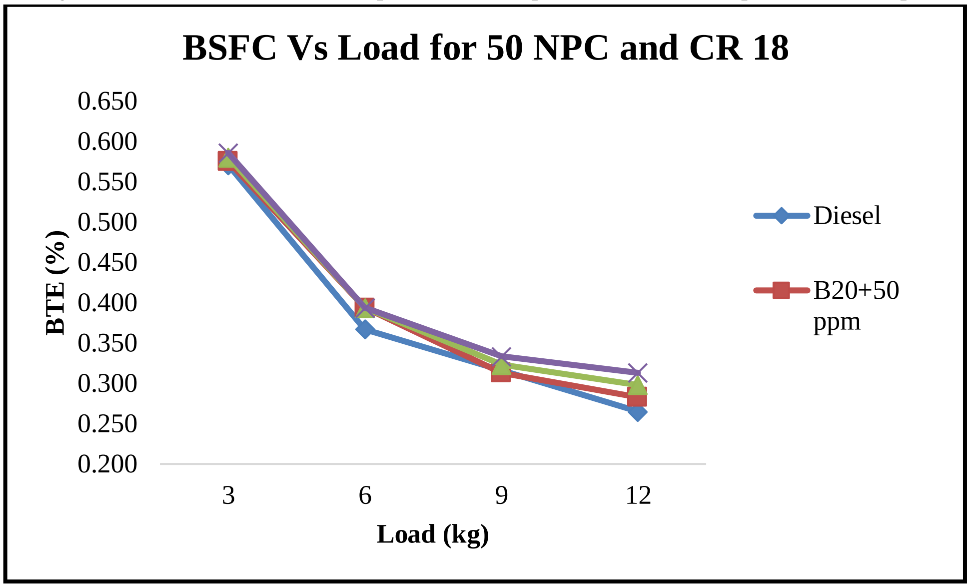

Fig. 6 Break specific fuel consumption w.r.t. CR.

Brake specific fuel consumption

Fig shows that the variation in brake specific fuel consumption with respect to load for different value of compression ratio. As compression ratio increases brake specific fuel consumption goes decrease and brake thermal efficiency increases at full load at 22 compression ratio brake specific fuel consumption 0.29kg/kwh and at compression ratio 18 it is 0.31 kg/kwh.When the load is increased, the temperature and pressure of the combustion process rise, causing the BSFC to fall. [19].Peak pressure of BD2 fuel blend increases from 62.81 bar at 25% load (3kg) to 85.02 bar at 100 % load (12kg).

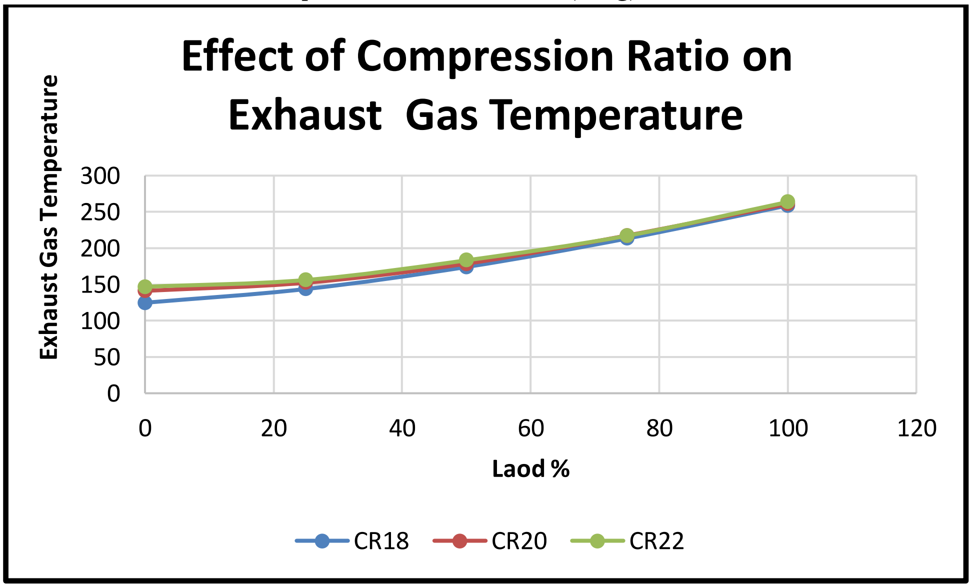

Fig. 7 Exhaust gas temperature w.r.t. CR.

At the higher compression Ratio delay period reduced and combustion take place at top dead centre it result into the increase the exhaust gas temperature at higher compression ratio. At full load at compression ratio 18, 20 and 22 Exhaust gas temperature was recorded 258.83, 260.85 and 263.64 respectively.

Conclusions:

The above work examined the production of biofuels from crude cotton seed oil with NPC and experimentally examined the effect of all performance parameters, including blends of biofuels with NPC and diesel fuel. The result of this experiment is summarized as follows,

1. Biofuel are produced from non-edible cottonseed oil by transesterification.
2. A maximum 76 percent biofuel production was found at 20 percent of methanol and 0.5 percent of NaoH at 55^0C.
3. Brake thermal efficiency is relatively lower than pure diesel due to the lower heating value of the engine. However higher viscosity, higher density volatility of biofuel may be the additional reasons for the reduction in efficiency with biofuel and diesel blend.
4. As blend percentage of biofuel increases break thermal efficiency decreases but with increase in compression ratio at higher side brake thermal efficiency as well as exhaust gas temperature increases.
5. When the compression ratio and load are both increased, the BTE value also goes up. The BTE maximum with Compression Ratio and nanoparticle concentration

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