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Enhancement in Performance and Emission Characteristics of Soybean Biodiesel by using Sr-ZnO Nanoadditives in VCR Engine

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Abstract

In present literature effect of strontium zinc oxide (Sr-ZnO) nanoparticle on soybean biodiesel were studied at 21.5 compression ratio various tests were carried out to find out optimum useful compression ratio for soybean nanofuel at three different doses level. We found very similar characteristics in soybean biodiesel as compared to diesel fuel. Also, huge quantity of soybean is available in Asian subcontinent. Although some of limitations like poor flow properties, high density, low heating value, high NOx emission and low cetane number etc. that can be overcome by addition of suitable nanoadditives. Soybean biodiesel was prepared with transesterification process. Morphological study of nano-particles was done to understand its behavior. Sodium dodecyl sulfate (SDS) surfactant was used to stabilize nanosolution. After making combination of all possible nanofuel blends physicochemical properties of blends was tested in Apex innovation laboratory Sangli as per American Society for Testing and Materials (ASTM) standards. Performance and emissions readings were taken at different loads and compression ratios from the different results it was found that with addition of Sr-ZnO nano-particles break thermal efficiency (BTE) was increased by 9.66%, brake specific fuel consumption (BSFC) decreases by 7.22%; also carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NOX) emissions was reduced significantly because of better combustion efficiency. At high load NOx increases with comparable amount with all fuel blends. Further NOx can be minimized by exhaust gas recirculation (EGR) method.

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Keywords: Soybean biodiesel, morphology, VCR engine, emission, performance.

INTRODUCTION

The increased global demand of petroleum at the same time scarcity of fossil fuels creates big problem for the world. Bio diesel is the best alternative fuel for petroleum [1]. By using suitable nanoadditives, we can improve combustion phenomenon as well as reduce emissions. Variable Compression Ratio (VCR) engine is a key tool to find out higher useful compression ratio for any Bio fuel blend; hence by using suitable nanoadditives and proper compression ratio we can give best alternative to fossil fuels [2]. It's also observed because of Nanoadditives improvement in reactive surface area and better combustion take place it enhances Brake thermal efficiency and reduce specific fuel consumption it also reduces carbon monoxide hydrocarbon and smoke density at the same time

NOx increases [3]. By addition of suitable Nano-particles, we can enhance performance parameters like Brake thermal efficiency and the same time BSFC get reduced [4]. Hence uniform and proper combustion process at higher compression ratio also reduces smoke density as well as reduces ignition delay period. Complete combustion of fuel leading to a higher temperature hence NOx are produced by addition of copper coated zinc oxide nano-particles [5].

These biofuels have certain limitations and drawbacks like higher density, poor cold flow properties, high viscosity and poor cetane number. These limitations can be overcome with suitable nanoadditives in particular biodiesel, using higher useful compression ratio etc. In this regards VCR engine plays a very vital role [6].

MATERIALS AND METHODS

Preparation of Soybean Biodiesel

Preparation of soybean biodiesel by using proper grains of soybean and drying properly oil can extract with mechanical press for proper result electrical heater was used during extraction of oil prove that oil processed with 18% of methanol and 1.5% of sodium methoxide as a catalyst at 65°C for 2 hours, and ultrasonicator was used for proper mixing after transesterification process by using ultrasonic homogeneous mixture was made.

This proper mix solution including surfactant and nanoadditives was tested with physicochemical properties at Apex innovations Sangli.

The nanoparticle was prepared by homogenous addition method and various characterization techniques were carried out to verify the significance of structural and physical properties of Sr-ZnO.

Characterization of Nanoparticle

Characterization of nano-particles was performed at central instrumentation facility, Savitribai Phule Pune University, Pune. Figures 1 and 2 show the observations under two magnification levels of 500 nm (nanometer) and 400 nm respectively. The brighter spots reveal elevated crystalline nature of the material. The average particle size was observed to be in approximate range of 3.105 nm.

Figure 2 reveals the Energy-dispersive X-ray spectroscopy of ZnO nano-particles and the content of Sr with atomic percentage is 7 and Zn 6 respectively.

By using ultrasonicator as shown in Figure 3, homogeneous mixture of soybean biodiesel and Sr-ZnO nano-particles was made. Table 1 shows Physiochemical properties of well mixed solution were tested in Apex innovation laboratory, Sangali.

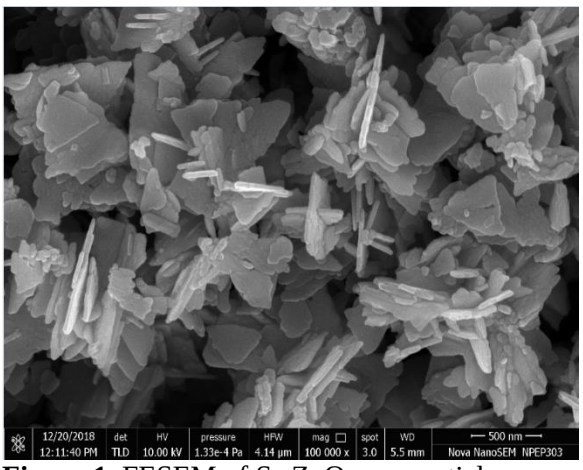

Figure 1. FESEM of Sr-ZnO nanoparticle.

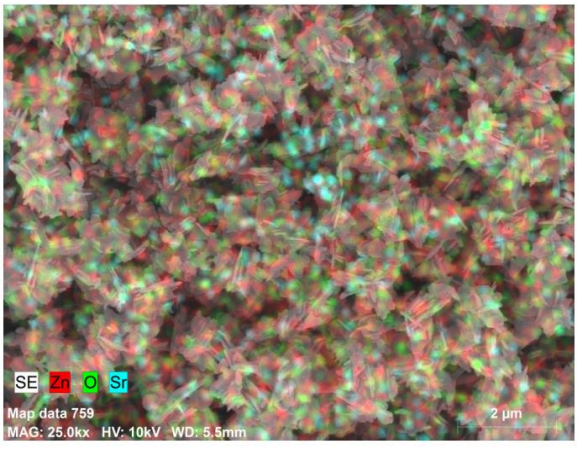

Figure 2. EDS of Sr-ZnO nanoparticle.

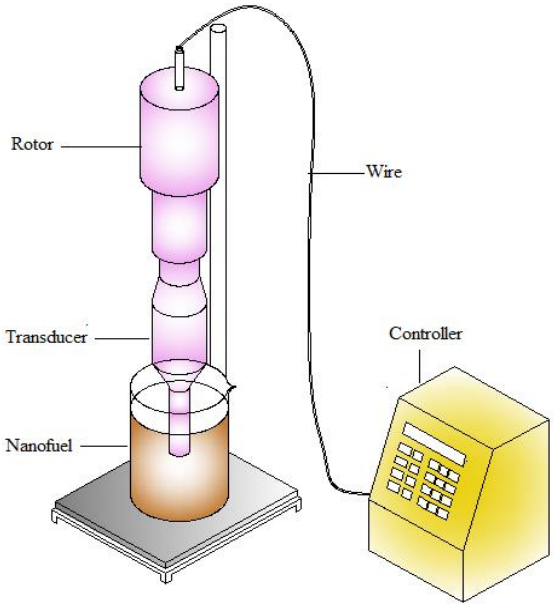

Figure 3. Schematic sketch of ultrasonicator.

Table 1. Physiochemical properties of fuel blends.

S. N.	Test	Units	ASTM Standards	Test Limits ASTM	Diesel	Soybean	SBME 30	SBME30SrZnO50	SBME30SrZnO75
1	Density @250C	kg/m^3	ASTM D 287	0.883	828	875	845	840	841
2	Specific Gravity	-	ASTM D 287	0.883	0.828	0.875	0.845	0.840	0.841
3	Gross Calorific Value	kJ/kg	ASTM D 4809	9404	44000	40900	42400	42700	42510
4	Flash Point	°C	ASTM D 93–58T	4.29	68	89	81	78	80
5	Fire Point	°C	ASTM D 93–58T	93	77	99	87	83	85
6	Cloud Point	°C	ASTM D 97	107	-7	-3	-4	-5	-4
7	Pour Point	°C	ASTM D 97	4	-11	-6	-8	-10	-9
8	Kinematic Viscosity@400C	cSt	ASTM D 445	0	2.81	4.74	5.4	5.3	5.4

Engine specifications

Model—VCR
RPM—1800.
Stroke—110 mm
Rated Power—5 HP
Bore—87.5 mm
CR—16 to 22 for Compression Ignition (CI) mode

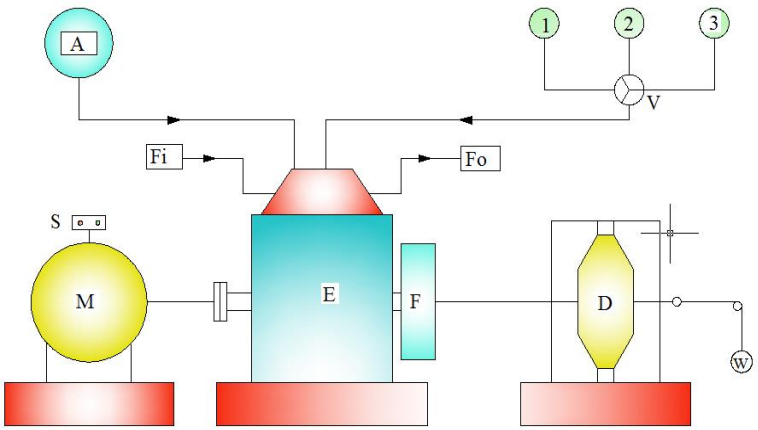

Figure 4. Variable compression ratio engine (VCR) test rig setup.

Where,

A—Air Box	M—Motor	E—Engine
1,2,3—Fuel tanks	M—Starter Motor	F—Flywheel
D—Dynamometer	W—Dead Weight	S—Starter
Fi—Fuel Inlet	Fo—Fuel Outlet	

TEST SETUP

Testing of engine was performed at Apex innovations laboratory Sangli. VCR engine test rig shown in Figure 4. Consists of displacement block assembly along with cylinder sleeve. The test rig consists of different fuel tanks and three ways cock assisted for the different fuel blends. In case of petrol mode fuel injector is replaced by spark plug and fuel supply system is replaced by carburetor hence the same engine can be used for different fuels. Unique feature of variable compression ratio (VCR) engine is compression ratio can change by increasing or decreasing combustion chamber volume, at higher compression ratio will get higher thermal efficiency and at the same time when engine operate at low compression ratio it prevents knocking, because of this facility VCR engine give more power for the same engine dimension.

UNCERTAINTY ANALYSIS

The uncertainty analysis measures the engine error and predicted errors during the experimentation are shown in Table 2.

Table 2. Uncertainty analysis.

Parameters	Accuracy Level	Uncertainty %
Brake power	-	± 0.5
BTE (%)	-	± 0.5
BSFC (%)	-	± 0.5
Carbon monoxide (CO)	± 0.02%	± 0.4
Hydrocarbons(HC)	±7ppm	± 0.6
Nitrogen oxide (NOx)	±7ppm	± 0.3

RESULTS AND DISCUSSIONS

Effect of Sr-ZnO Nanoadditives and Soybean Oil Blend on the Engine Performance

Brake Thermal Efficiency

Brake thermal efficiency is strongly depending upon load on the engine, Figure 5 shows as the load increases Brake thermal efficiency increases up to 80% after that graph become flat load is directly proportional to BTE. Also, it was affected by compression ratio. As compression ratio increase combustion pressure increases. Pressure also increases torque which increases Brake thermal efficiency but this parameter has less effect on engine as compared to load on the engine. At higher load maximum temperature reached at combustion chamber at this stage less heat losses as compared to low load which indirectly increases thermal efficiency of the engine [7].

Figure 5 illustrate diesel fuel having higher Brake thermal efficiency as compared to other fuels. Addition of SrZnO50 nanoparticle in SB30 enhances combustion properties of the mixture and hence this blend shows increment in Brake thermal efficiency as compared to SB30SrZnO75. Nanoadditives improves net heating value of nanofuel blends thus Brake power increases indirectly BTE improves. Graph indicates by addition of nanoadditives Brake thermal efficiency (BTE) is enhanced by 9.66%.

Brake Specific Fuel Consumption

Figure 6 shows BSFC increases with increase in load and reported minimum BSFC at higher compression ratio, Range of BSFC lie within 0.2 to 0.5 kg/kw.h. BSFC is majorly depending on combustion characteristics. In case of diesel engine at higher load there is minimum heat loss so for obtaining particular Brake power BSFC is minimum for each fuel blend. All tested fuel blend shows

increase in BSFC as load increases [8]. Diesel fuel having lower BSFC as compared to other fuel blends because of its better combustion properties, by addition of nanoadditives in biofuel physicochemical properties are improved SB30SrZnO50 shows better combustion properties and lower BSFC as compared to other nanofuel blends. As shown in Figure 6. Addition of nanoadditives improves heat content hence average Brake specific fuel consumption (BSFC) decreased by 7.22%.

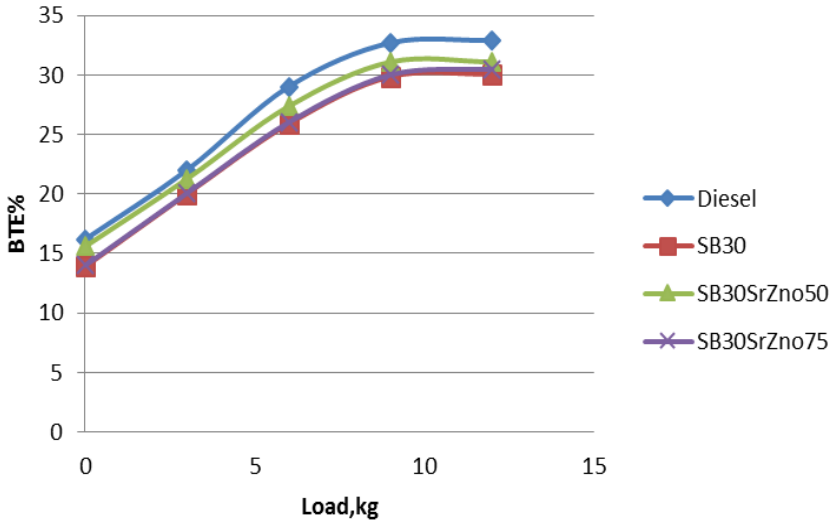

Figure 5. The variation of BTE with load.

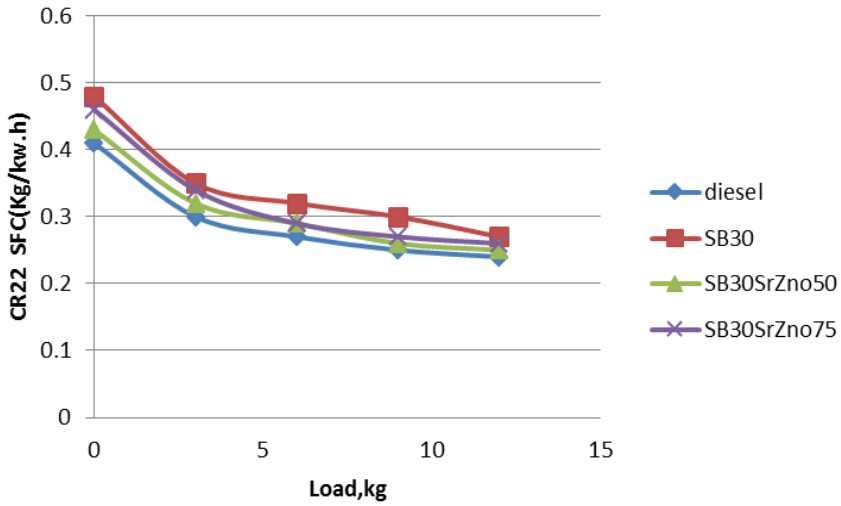

Figure 6. The variation of BSFC with load.

Effect of Sr-ZnO Nanoadditives and Soybean Biodiesel Blend on the Engine Emissions

Carbon Monoxide

Figure 7 illustrate nature of CO in all load conditions, generally CO produces due to incomplete combustion of fuel particles inside the combustion chamber. In presence of insufficient oxygen for combustion CO not completely get converted into CO_2 hence CO is formed, Figure 7 shows that initially CO get reduced up to 50% of load and after that again it increases as the load increases the amount of oxygen required for combustion is get reduced and hence proper combustion of biofuel is not possible although by adding particular nanoadditives combustion properties are improved and hence SB30SrZnO50 shown better combustion properties and less CO formation as compared to other nanofuel blends. Complete combustion of fuel reduces unburned carbon thus overall CO emissions are decreased by 5.27%.

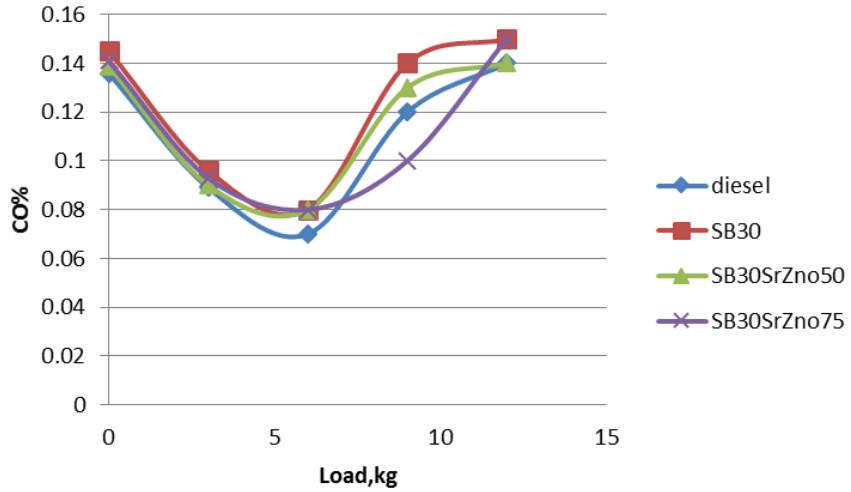

Figure 7. The variation of CO with load.

Hydrocarbons

Figure 8 indicates increment in HC emissions with load variation. HC is mostly dependent on compression ratio, HC decreases at higher compression ratio. With increase in compression ratio combustion pressure increases, because of high pressure very fine particle are produced and hence delay period reduces and proper combustion of fuel is taken place. Soybean biodiesel having higher density as compared to diesel addition of nanoadditives in soybean biodiesel which reduces density of soybean biodiesel thus fuel spray characteristics improves and hence HC emissions decreases SB30SrZnO50 having less HC emissions as compared to other nanofuel blends [9, 10]. As ignition delay period decreases it enhances proper combustion of nanofuel Figure 8 clearly indicates HC emissions reduced by 22.31% by addition of nanoadditives.

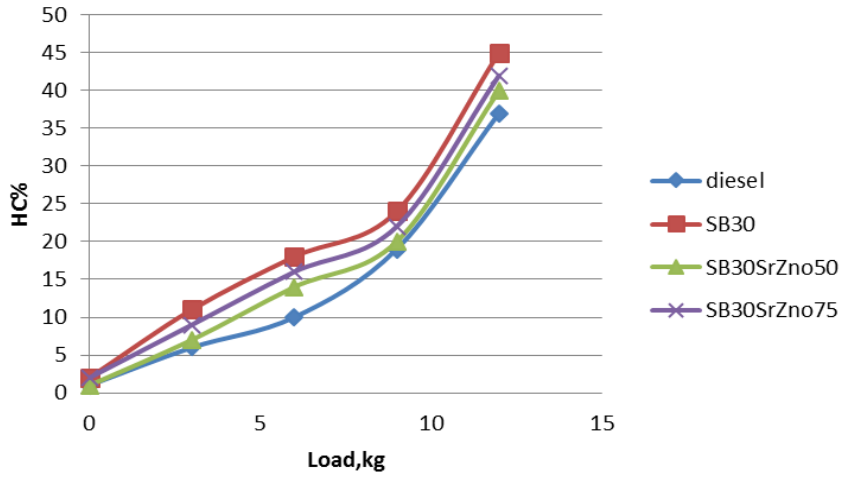

Figure 8. The variation of HC with load.

Nitrogen Oxide

NO_X emissions for all tested blends with variation of load are shown in the Figure 9. NOx is minimum at low load and it increases as the load increases. With increases in load combustion pressure increases which is directly proportional to temperature. At temperature beyond 1100°C NOx is produced. Soybean biodiesel having high oxygen content in the fuel these leads to complete combustion of fuel and hence at a high temperature beyond 1100°C NOx are produced; nanoparticle also enhances the combustion properties of fuel blends hence Figure 9 shows all nanofuel shows increment in NOx emissions as compared to diesel and biodiesel blends.

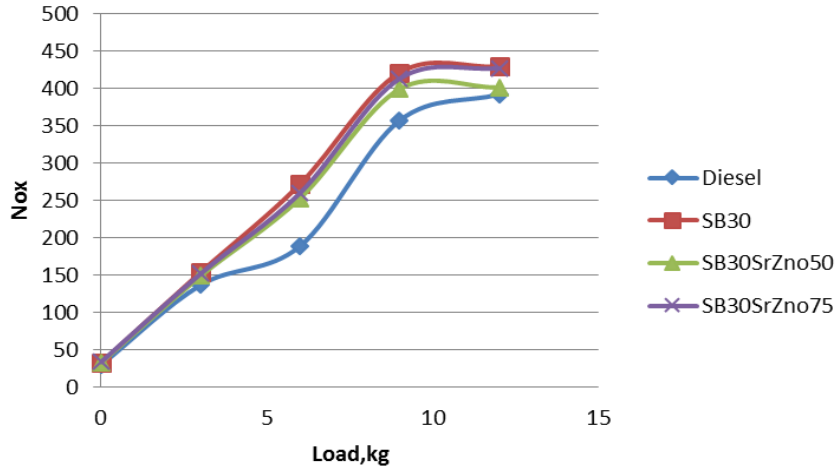

Figure 9. The variation of NOx with load.

CONCLUSIONS

The present study focuses on the effect of Sr-ZnO nanoparticle on performance and emission characteristics of soybean biodiesel using variable compression ratio engine. Emulsion of Sr-ZnO in soybean biodiesel improves performance and emission parameters.

Addition of Sr-ZnO nano-particles Brake thermal efficiency (BTE) is enhanced by 9.66% and Brake specific fuel consumption (BSFC) decreased by 7.22%. All performance parameters improved at CR 21.5 and at SB30SrZnO50 nanofuel blend.

All emissions except NOx are found to be decreased with the addition of nano-particles. CO, HC emissions are decreased by 5.27%, and 22.31% respectively. NOx emissions increases due to more oxygen content for all fuel blends with nanoparticle addition.

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