Experimental investigation on a symmetrically stepped curved v piston (SSCVP) for DI-diesel engine fuelled with sesame biodiesel and its blends with diesel using additive

K. Satish Kumar[1] and Dr.Smt.G.Prasanthi[2]

[1]PG Research Scholar, Advanced IC Engines, Dept. of Mechanical Engg., JNTUCEA, Ananthapuramu-515002, AP, India

[2]Professor of Mechanical Engg., Director, Faculty Development & IQAC, JNTUA, Ananthapuramu-515002, AP, India

Abstract: In this investigation, the combustion, performance and emission characteristics of a diesel engine powered with symmetrically stepped curved-v piston (SSCVP) are studied. Engine tests have been carried out using standard diesel and biodiesel blends (S10-D90, S20-D80 and S30-D70). The S20-D80 blend gets better results compare to S10-D90 & S30-D70, and also adding different proportions of TBHQ additive to S20-D80 (S20-D80+500mg TBHQ and S20-D80+1000mg TBHQ). The engine with SSCV piston has shown improved performance characteristics, combustion characteristics and reduced hydrocarbon (HC), carbon monoxide (CO), and smoke emissions. Nevertheless, the nitrogen oxide emissions have been found to be slightly lower than the standard engine, this reduction in NO_X is due to addition of Tert-Butyl Hydroquinone (TBHQ) additive to sesame biodiesel blend (S20). The experimental investigation revealed that engine with SSCV piston with 20% blend using additive (S20-D80+500mg) resulted in 5.79%, 4.36% more prominent performance characteristics of brake thermal efficiency, specific fuel consumption and superior emission diminution of 15.49% of HC, 13.33% of CO, 9.44% of smoke opacity when compared with base diesel fuel using standard piston, despite marginal penalty of 1.43% of NO_X at 4.9 kW BP i.e. at 100% load condition. Combustion characteristics like cylinder pressure and heat release rate are superior for 20% blend using additive at peak load condition.

Keywords: Combustion improvement and Energy efficient, Sesame biodiesel, Turbulence Inducement and Tert-Butyl Hydroquinone (TBHQ) additive.

1 INTRODUCTION

The world's fossil fuel reserves are depleting at higher pace due to exponential growth of population and increased usage of technology. Developing countries like India, invest heavily on imports of petroleum fuels. In such countries most of automotive and transport vehicles run on diesel. Diesel fueled vehicles discharges considerable amount of pollutants like CO, UHC, NO_X and Smoke which are very harmful for environment and society. However to overcome this threat, the biofuels are being used in IC engines as alternate fuels. Traditional oilseed feedstock for biodiesel production predominantly includes soyabean, rapeseed, canola, palm, corn, sunflower, cottonseed, peanut, sesame (Sesamum indicum) and coconut oil [1]. The long chain hydrocarbon structure, vegetable oils have good ignition characteristics, however they cause serious problems such as carbon deposits buildup, poor durability, high density, high viscosity, lower calorific value, more molecular weight and poor combustion. These problems lead to poor thermal efficiency, while using vegetable oil in the engine. These problems can be rectified by different methods that are used to reduce the viscosity of vegetable oils. The methods are transesterification, dilution and cracking method [2]. The transesterification of vegetable oil gives better performance when compared to straight vegetable oil [3]. Phan and Phan, carried out transesterification of waste cooking oils with methanol and KOH as catalyst. They obtained a maximum yield of 90% for a molar ratio of 8:1 at a temperature of 50°C with 0.75 wt% KOH [4].

The performance and emission characteristics of biodiesel for different vegetable oils have been presented by various authors in various papers, and they have been proven successful alternative fuels (viz. mustard oil [5], cotton seed oil [6], kapok methyl ester [7], and waste cooking oil [8]). Study shows that, on the mass basis, biodiesel has an energy content of about 12% less than petroleum based diesel fuel. It reduces unburned hydrocarbons (UHC), carbon monoxide (CO), and increase oxides of nitrogen (NOx) than diesel-fueled engine. The Neem methyl ester blends i.e., B10, B20, B30 and B40 are running normal during testing of diesel engine. B20 showed very close performance to diesel fuel [9]. "Here the 100% biodiesel is termed as biodiesel and the different blends of biodiesel with diesel fuel are termed as biodiesel mixtures. A few experimental investigations have been reported with a wide variety of metal oxide additives to biodiesel to improve the fuel properties and engine performance as well as to reduce emissions. Based on literature survey, the experimental investigation of antioxidant additives to biodiesel shows the emission levels of CO & HC are appreciably reduced [10 & 11]. Poor oxidation stability of biodiesel is the central problem associated with its commercial acceptance. To enhance the practical feasibility of biodiesel, antioxidant additives are added to increase its storage stability. It is quite possible that additives may affect other basic fuel properties of biodiesel. It observed that the kinematic viscosity is reduced at lower concentrations of antioxidant additives (500 ppm) and slightly increased at high concentrations (1000 ppm) but lower than that of pure biodiesel [12]. To improve the engine performance and reduce the emission level for diesel engine some of the authors focused on antioxidant additives to biodiesel [13 & 14]. In the present work, the influence of the addition of antioxidant additive of Tert-Butyl Hydroquinone (TBHQ), major physiochemical properties and the performance of sesame biodiesel is studied. The effect of antioxidant additive on biodiesel properties, engine performance and emission is examined with different dosing levels on a weight basis (500 & 1000mg) of TBHQ.

At present research is being carried on various techniques such as pre-combustion, post-combustion and engine design modification to enhance their performance and reduce their emission magnitudes [15]. The in-cylinder air motion, fuel injection timing, pressure and bowl dimensions are some of the important parameters that govern the performance, emission characteristics and the consequence of the combustion in the internal combustion engines [16 & 17]. Of these, combustion bowl's design plays a crucial role in monitoring the air and fuel mixture which has a direct impact on the performance and emission characteristics [18-24]. The diesel engine has been standardized for the usage of diesel and hence for using an alternative fuel some suitable modifications either in the engine or fuel can be made. In the present investigation doing research on piston bowl modification i.e. symmetrically stepped curved-v piston (SSCVP) with 6 swirl enhancement grooves which can improve the mixing of air/fuel mixture. The test fuel of 10%, 20% & 30% blends with diesel fuel is prepared based on volume basis and a step further, by adding different proportions of tert-butyl hydroquinone (TBHQ) additive to S20 blend by a magnitude of 500 mg and 1000mg. The SSCV piston is designed based on literature survey the following piston design and the biofuel with TBHQ additive has never been in the experimental study, the no one has done my combination.

2 MATERIALS AND METHODS

2.1 Test Fuels and Antioxidant Additives

2.1.1 Sesame oil;

The alternative fuel considered for this work is sesame oil, which has golden colour. For this research work locally produced sesame oil & sesame biodiesel are used as shown in Fig. 2.1 & 2.2. The chemical and physical property of sesame oil is characterized as shown in Table 1.

\ Fig. 2.1 Sesame Oil Fig. 2.2 Sesame Biodiesel Fig. 2.3 Tert-Butyl Hydroquinone additive

Table 2.1 Physical Properties of Diesel, Biodiesel mixtures

S.No	Characteristics	Unit	D100	Sesame oil	S100	S10	S20	S30	S20+500mg	S20+1000mg
1	Kinematic Viscosity @40ºC	m_2/s	2.95	5.2	3.8	3.22	3.28	3.37	3.18	3.05
2	Density @15.5ºC	kg/m_3	844	880	858	865	867	860	872	878
3	Calorific value	kJ/kg	44,120	39,480	40,900	42,050	41,000	39,100	41,180	41,198
4	Specific gravity		0.844	0.88	0.858	0.865	0.867	0.86	0.872	0.878
5	Flash point	ºC	66	345	142	74	81	89	83	87
6	Fire point	ºC	76	360	176	86	96	106	98	102
7	Cloud point	ºC	-6	-4	-6.3	-6.03	-6.06	-6.09	-6.15	-6.21
8	Cetane Number		49.7	36	42	48.93	51	51.36	53	52.5

2.1.2 Tert-Butyl Hydroquinone (TBHQ) Antioxidant Additive;

TBHQ is an antioxidant additive and is procured by artificial rancidification of edible fats and oils whether vegetable or animal based. It is very widely applied for increasing the shelf-life of these oils synthesis and is specifically used for stabilizing and preventing fats. TBHQ additive has an exceptional stabilizing effect in unsaturated fats, particularly in polyunsaturated vegetable oils and in edible animal fats.

3 OBJECTIVES

The main objective of the present investigation is to effectively utilize sesame oil as an alternate fuel in a diesel engine and thereby reducing the environmental problems caused by exhaust emissions.

- To investigate the engine characteristics fueled with sesame biodiesel and to study the effects of modified combustion chamber geometry (CCG) on DI diesel engine.
- To improve combustion quality by providing swirl enhancement grooves for increasing turbulence.
- To experimentally investigate the effects of CCG on DI diesel engine fuelled with sesame biodiesel.
- Reducing emissions by using biodiesel due to rich content of oxygen in biodiesel compare to diesel fuel.

- Reducing NO_X emissions by using tert-butyl hydroquinone (TBHQ) antioxidant additive.

4 EXPERIMENTAL SETUP

4.1 Engine Setup

A single cylinder, four stroke, direct injection (DI), water cooled, Kirloskar TV1 model diesel engine is used for the tests. The detailed technical specifications of the standard engine are given in Table 4.1. The engine operates at a constant speed of 1500 rpm. The standard engine has a hemispherical combustion chamber (HCC) with the overhead valve arrangements operated by push rods. This engine connected to eddy current type dynamometer and equipped with a MICO in line injection pump, which pressurizes and injects the fuel at a pressure of 200 bar. The cylinder pressure is measured by a piezoelectric pressure transducer fitted on the engine cylinder head and a crank angle encoder fitted on the flywheel. A three holed injector of diameter 0.3 mm is used, which injects the fuel in the form of fine spray. Both the pressure transducer and encoder signal are connected to the charge amplifier to condition the signals for combustion analysis using combustion analyzer. The engine combustion analyzer is used to evaluate and determine cylinder combustion characteristics. UBHC, CO_2 and CO are measured using a Crypton 290 series emission analyzer. NO_X emissions are measured using chemiluminescent type SIGNAL heated vacuum NO_x analyzer. The smoke intensity is measured with the help of the AVL 437 C Smoke meter. Fig. 4.1 shows the illustrative diagram of the experimental set-up and Fig. 4.2 shows the photography of experimental set up.

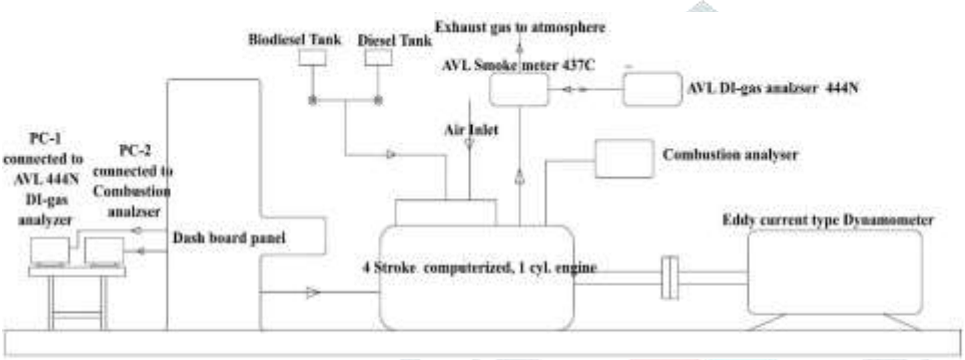

Fig. 4.1 Schematic Diagram of Experimental Setup

Fig. 4.2 Experimental Engine Setup

Table 4.1 Specifications of Test Engine

Engine make	Kirloskar TV1
Type	1 cylinder, 4 stroke, water cooled, vertical computerized diesel engine
Displacement	661 CC
Bore & Stroke	87.5mm & 110mm
Compression ratio	17.5:1
Fuel	Diesel
Rated brake power	5.2kW at 1500rpm
Ignition system	Compression ignition
Injection timing	23°bTDC (rated)
Injection pressure	200 bar
Combustion chamber	Hemispherical combustion chamber
Nozzle hole Ø & number	0.3 mm & 3 holes

Table 4.2 Uncertainties in Measured Parameters

S.No	Parameters	Systematic errors
1	Speed	1 rpm
2	Load	0.02 kg
3	Time	0.1 s
4	Brake power	0.4 kW
5	Temperature	$1^{O}C$
6	NO_X	10 ppm
7	CO	0.02%
8	CO_2	0.02%
9	HC	11 ppm
10	Smoke	1 Hsu

4.2 Engine Modifications

In the present study, the piston bowl of the standard engine combustion chamber is modified to study the performance, combustion and emission characteristics of sesame biodiesel fueled DI diesel engine. The standard hemispherical combustion chamber (HCC) is designed for DI diesel engine, but when the engine is run by biodiesel, the need for modification in the combustion chamber has to be taken into account to evaluate its performance. The improved air motion in the combustion chamber due to its geometry facilitates the mixture formation of biodiesel with air, thereby increasing brake thermal efficiency and lowering the specific fuel consumption. Swirl enhancement grooves are provided in the piston crown to enhance the biodiesel air mixing by improving the swirling motion. The standard piston, fabricated SSCV piston and schematic representation of SSCV piston are shown in Fig: 4.3, 4.4 & 4.5. The dimensions of the pistons are chosen so as to maintain the same piston bowl volume. The fuel injection quantity is maintained same for both the piston geometries and it is chosen so as to represent the full load consumption. For a better performance of DI diesel engine the injected fuel has to evaporate, mix and distribute within the combustion chamber uniformly. This can be achieved by two methods: a) by employing a high pressure injector, b) by modification of the combustion chamber geometry with various bowl geometries to increase the swirl and hence turbulence. The first option requires additional electronics and additional parasitic losses. Moreover the mounting problems with the existing low speed mechanical injection system require extensive modification in the fuel circuit. Hence a better option would be to enhance the turbulence by means of piston modification to generate better squish and swirl. Air motion inside the engine cylinder plays an important role, and they have a significant impact on the combustion quality.

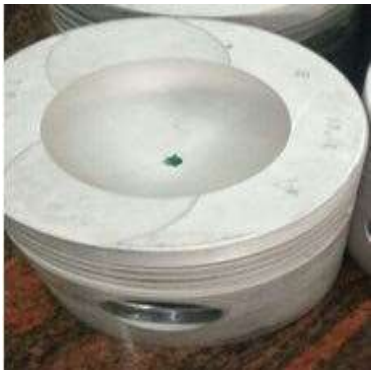

Fig. 4.3 Standard piston (SP)

Fig. 4.4 Fabricated SSCV piston

Fig.4.5 Schematic representation of SSCV piston

4.3 Test Method

Tests are carried out using diesel and sesame biodiesel. The experiment is conducted with three phases. In the first phase, the experimental investigations are carried to get base line parameters using standard diesel as fuel for both standard piston (SP) and SSCV piston on the test engine. In the second phase, the experimental investigation is carried out using sesame biodiesel blends (i.e. S10-D90, S20-D80 & S30-D70) as a fuel in the engine with using modified piston i.e. SSCV piston. In the third phase, the experimental investigation is carried out by adding TBHQ additive by various proportions (i.e. 500mg & 1000mg) for best blend (S20-D80) for reducing NO_X emissions and increasing storage stability of fuel, The blends S20-D80+500mg & S20-D80+1000mg as a fuel in the engine with using modified piston. In the experimental investigation, different instruments are used for the measurement of different parameters. Errors and uncertainties in the experiment may occur due to the selection of instruments, working condition, calibration, environment, observation, and the method of conduct of the tests. Uncertainty analysis is necessary to prove the accuracy of the experiment. The instruments and equipment are made by different manufacturers using different technologies. Hence the uncertainty occurs due to fixed or random errors. The uncertainties in the determined parameters are estimated based on analytical methods. The uncertainties computed for the measured quantities are given in Table 4.2.

5 RESULTS AND DISCUSSION

5.1 Performance Analysis

5.1.1 Brake thermal efficiency (BTE);

BTE is defined as the ratio of brake power to product of fuel consumption and calorific value. BTE increases with increase in BP, Fig. 5.1 shows the variation of BTE with BP for SSCV piston and standard piston fueled with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg). As the sesame biodiesel concentration increased in the diesel fuel the BTE decreases due to increase in viscosity of fuel. By considering fuel the BTE in the S20-D80 blend of SSCV piston is nearest to diesel fuel of standard piston. If TBHQ additive added in the S20-D80 blend by a proportion of 500 & 1000mg then BTE increases in both, but by comparing two additive proportions, the 500mg proportion BTE is higher than 1000mg. By considering pistons the BTE of SSCV piston is higher than standard piston fueled with diesel.

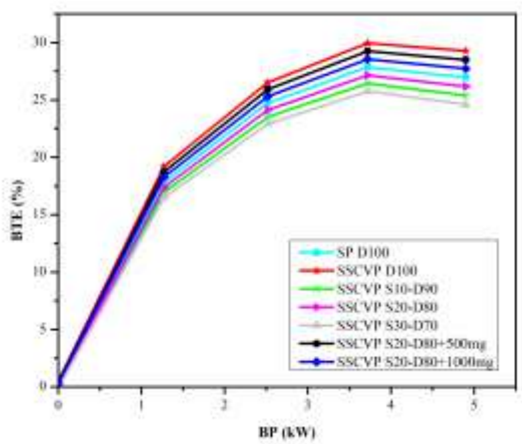

Fig. 5.1 Brake thermal efficiency rate variation

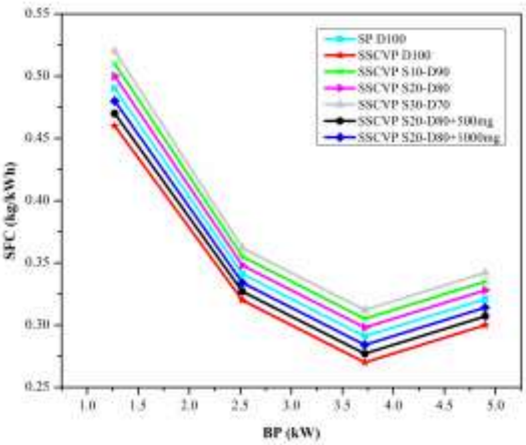

Fig. 5.2 Specific fuel consumption rate variation

The maximum BTE of SSCV piston is 7.54% higher than standard piston fueled with diesel at 3.72 kW BP (i.e. 29.95% & 27.85%) is observed. A slight fluctuation in BTE at maximum BP i.e. 3.72 has 8.68% higher BTE for SSCV piston than standard piston fueled with diesel but a slight decrease in BTE for BP of 4.9 kW (i.e. 29.28% & 26.94%) compare to 3.72 kW BP (i.e. 29.95% & 27.85%). The outcome showed that the BTE of the biodiesel blend S20-D80+500mg operated with

SSCV piston is closer to diesel fuel of same piston (i.e. 29.25% at 3.72 kW BP & 28.5% at 4.9 kW BP). By comparing standard piston with diesel and SSCV piston with S20-D80+500mg blend, the SSCV piston has 5.02% higher BTE at 3.72 kW BP, whereas 5.79% higher BTE at 4.9 kW BP.

5.1.2 Specific fuel consumption (SFC);

SFC is the amount of fuel consumed by an engine for each unit of power output. SFC is the mirror image of BTE. The variation in SFC with BP for standard piston and SSCV piston operated engine with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg) are shown in Fig 5.2. SFC is independent of the fuel and energy input required to develop unit power. As the sesame biodiesel concentration increased in the diesel fuel the SFC increases due to increase in viscosity and decrease in calorific value of fuel. The SFC in the S20-D80 blend of SSCV piston is nearest to diesel fuel of standard piston. If TBHQ additive added to S20-D80 blend in the proportion of 500 & 1000mg then SFC decreases in both 500mg & 1000mg, but by comparing additive proportion of both the SFC of 500mg is lesser than 1000mg. By considering pistons the SFC of SSCV piston is lower than standard piston fueled with diesel. The minimum SFC of SSCV piston is 7.21% lesser than standard piston fueled with diesel at 3.72 kW BP (i.e. 0.27 & 0.291 kg/kWh) is observed. A slight fluctuation in SFC at maximum BP i.e. 4.9 kW has 6.54% lesser SFC for SSCV piston than standard piston fueled with diesel but a slight increase in SFC for BP of 4.9 kW (i.e. 0.3 & 0.321 kg/ kWh) compare to 3.72 kW (i.e. 0.27 & 0.291 kg/kWh). The outcome showed that the SFC of the biodiesel blend S20-D80+500mg operated with SSCV piston is closer to diesel fuel of same piston (i.e. 0.277 kg/kWh at 3.72 kW BP & 0.307 kg/kWh at 4.9 kW BP). By compare standard piston with diesel and SSCV piston with S20-D80+500mg blend, the SSCV piston has 4.81% lesser SFC at 3.72 kW BP whereas 4.36% lesser SFC at 4.9 kW BP.

5.2 Combustion Analysis

5.2.1 Cylinder pressure;

The cylinder pressure is the pressure in the engine cylinder during the 4 strokes of engine operation (intake, compression, combustion & expansion, and exhaust). The pressure during expansion is the most important, because i.e. the cylinder pressure pushing on the piston to produce power. The cylinder pressure increases with increase in crank angle at peak point the cylinder has maximum pressure approximately at 5° of crank angle or at TDC, Fig. 4.3 shows the variation of cylinder pressure with crank angle for SSCV piston and standard piston fueled with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg). As the sesame biodiesel concentration increased in the diesel fuel the cylinder pressure decreases due to increase in viscosity of fuel causes decrease in temperature whereas temperature and pressure are directly proportional to each other. By considering fuel the BTE in the S20-D80 blend of SSCV piston is higher than that of S10-D80 & S30-D70. If TBHQ additive added in the S20-D80 blend in the proportion of 500 & 1000mg then cylinder pressure increases in both, but by comparing additive proportion of both, the cylinder pressure of 500mg proportion higher than that of 1000mg. By considering pistons the cylinder pressure of SSCV piston is higher than standard piston irrespective of fuels. The maximum cylinder pressure of 89.64 bar & 66 bar are observed for SSCV piston & standard piston fueled with diesel. The outcome showed that the cylinder pressure of the biodiesel blend S20-D80+500mg operated engine with SSCV piston has a cylinder pressure of 83.82 bar is observed which is closer to diesel fuel of same piston.

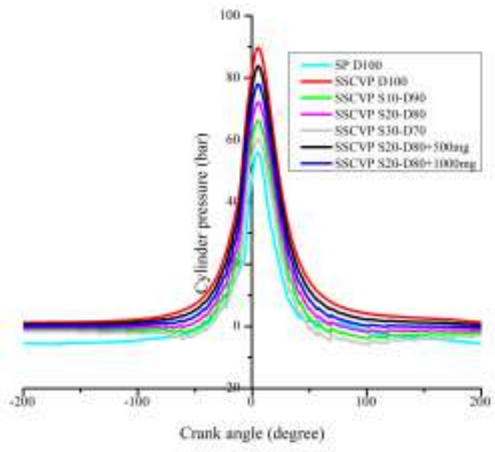

Fig. 5.3 Cylinder Pressure Variation

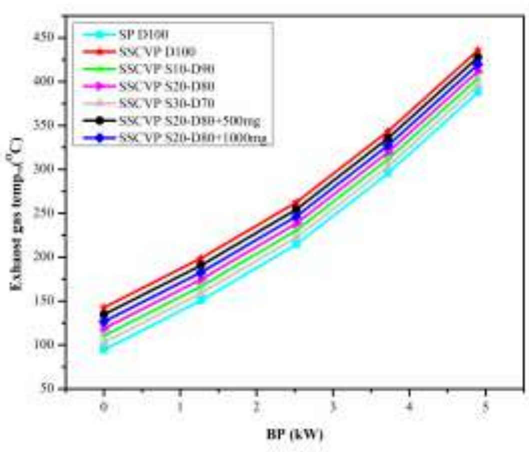

Fig. 5.4 Exhaust Gas Temperature Variations

5.2.2 Exhaust gas temperature (EGT);

EGT is a measurement of the temperature of the exhaust gases at the exhaust manifold. As the temperature of the exhaust gas varies with the ratio of fuel to air entering the cylinder, it can be used as a basis for regulating the fuel/air mixture entering the engine. EGT increases with increase in BP, Fig. 5.4 shows the variation of EGT with BP for SSCV piston and standard piston fueled with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg). As the sesame biodiesel concentration increased in the diesel fuel the EGT decreases due to increase in viscosity of fuel. By considering fuel the EGT in the S20-

D80 blend of SSCV piston is higher than that of S10-D90 & S30-D70. If TBHQ additive added in the S20-D80 blend in the proportion of 500 & 1000mg then EGT increases in both, but by comparing additive proportion both, the 500mg proportion EGT is higher than 1000mg. By considering pistons the EGT of SSCV piston is higher than standard piston irrespective of fuel. The maximum EGT of 435.68 ^{O}C & 387.68 ^{O}C are observed for SSCV piston & standard piston fueled with diesel at 4.9 kW BP (i.e. at 100% load). The outcome showed that exhaust gas temperature of the biodiesel blend S20+500mg has exhaust gas temperature of 427.68 ^{o}C which is closer to diesel fuel operated with SSCV piston.

5.2.3 Net Heat release rate (NHRR);

Fig. 5.5 shows the variation of NHRR with crank angle for SSCV piston and standard piston fueled with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg). If TBHQ additive added in the S20-D80 blend in the proportion of 500 & 1000mg then NHRR increases in both, but by comparing additive proportion the 500mg proportion NHRR is higher than that of 1000mg. By considering pistons, the NHRR of SSCV piston is higher than that of standard piston irrespective of fuels. The maximum NHRR of 103 & 62.65 J/deg are observed for SSCV piston & standard piston fueled with diesel. The outcome showed that the NHRR of the biodiesel blend S20-D80+500mg has 92 J/deg which is closer to diesel fuel when engine operated on a SSCV piston.

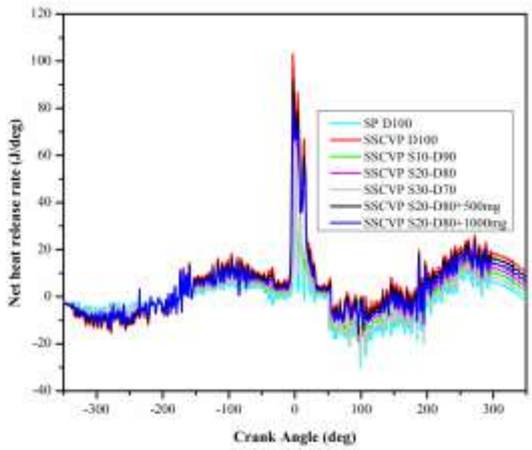

Fig. 5.5 Net Heat Release Rate Variation

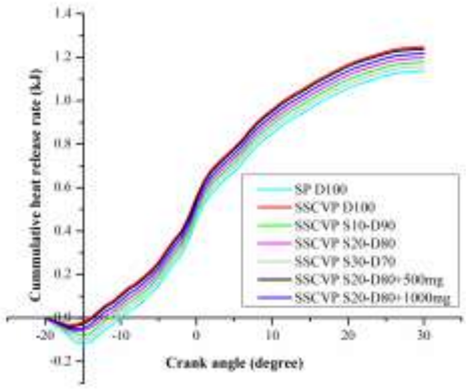

Fig. 5.6 Cumulative Heat Release Rate Variation

5.2.4 Cumulative heat release rate (CHRR);

Fig. 5.6 shows the variation of CHRR with crank angle for SSCV piston and standard piston fueled with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg). As the sesame biodiesel concentration increased in the diesel fuel the CHRR decreases due to increase in viscosity of fuel and decrease in calorific value. By considering fuel the CHRR in the S20-D80 blend of SSCV piston is higher than that of S10-D90 & S30-D70. If TBHQ additive added in the S20-D80 blend in the proportion of 500 & 1000mg then CHRR increases in both, but by comparing additive proportion the 500mg proportion CHRR is higher than that of 1000mg. By considering pistons, the CHRR of SSCV piston is higher than that of standard piston irrespective of fuels. The maximum CHRR of 1.2481 kJ & 1.1381 kJ are observed for SSCV piston & standard piston fueled with diesel. The outcome showed that the CHRR of the biodiesel blend S20-D80+500mg has 1.2381 kJ which is closer to diesel fuel when engine operated on a SSCV piston.

5.3 Emission Analysis

5.3.1 Carbon monoxide (CO);

CO emissions increase with increase in BP, Fig. 5.7 shows the variation of CO with BP for SSCV piston and standard piston fueled with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg). As the sesame biodiesel concentration increased in the diesel fuel the CO emissions decreases compared to diesel fuel due to increase in oxygen content of fuel. By considering fuel the CO emissions in the S20-D80 blend of SSCV piston is lesser compared to S10-D80, S30-D70 & Diesel fuel. If TBHQ additive added in the S20-D80 blend in the proportion of 500 & 1000mg then CO emissions decrease in both, but by comparing additive proportions the 500mg proportion CO emissions are lesser than 1000mg. By considering pistons the CO emissions of SSCV piston are lesser than that of standard piston irrespective of fuel. The minimum CO emissions of SSCV piston are 4.76% lesser than standard piston fueled with diesel at 4.9 kW BP (i.e. 0.20% & 0.21%) are observed. The outcome shows that the CO emissions of the biodiesel blend S20-D80+500mg operated with SSCV piston is lesser than diesel fuel (i.e. 0.182% & 0.20% at 4.9 kW BP). By comparing standard piston with diesel & SSCV piston with S20-D80+500mg blend, the SSCV piston has 13.33% lesser CO emissions at 4.9 kW BP.

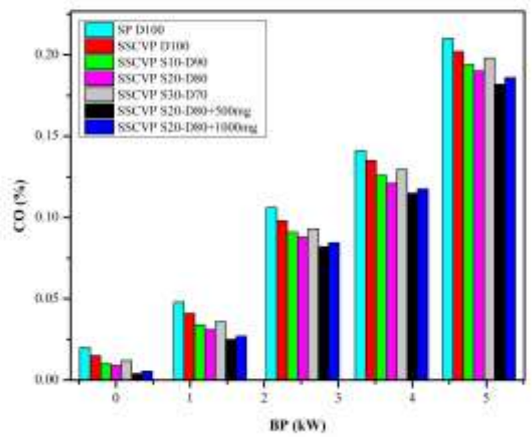

Fig. 5.7 Carbon Monoxide Variations

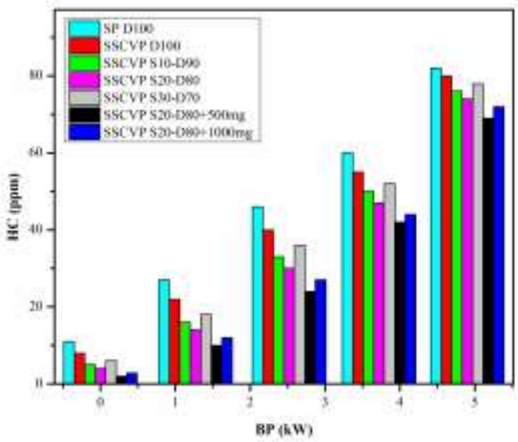

Fig. 5.8 Hydrocarbons Variations

5.3.2 Hydrocarbon (HC);

Hydrocarbons emissions result from in-complete fuel combustion and from fuel evaporation. The HC emissions increase with increase in BP. The variation in HC emissions with BP for standard piston and SSCV piston operated engine with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg) are shown in Fig. 5.8. As the sesame biodiesel concentration increased in the diesel fuel the HC emissions decrease due to increase in oxygen content of fuel as well as turbulence created by SSCV piston, by creating turbulence and enough oxygen provides complete combustion. The HC emissions in the S20-D80 blend of SSCV piston which is lesser than S10-D90 & S30-D70. If TBHQ additive added in the S20-D80 blend in a proportion of 500 & 1000mg then HC emissions decrease in both, but by comparing additive proportion of both, the HC emissions of 500mg proportion is lesser than 1000mg. By considering pistons the HC emissions of SSCV piston is lower than standard piston fueled with diesel. The minimum HC emissions of 78 ppm & 82 ppm are observed for SSCV piston & standard piston fueled with diesel. The outcome shows that the HC emissions of the biodiesel blend S20-D80+500mg operated with SSCV piston are 72 ppm which is lesser than diesel fuel. By comparing standard piston with diesel & SSCV piston with S20-D80+500mg blend, the SSCV piston has 15.44% lesser CO emissions at 4.9 kW BP.

5.3.3 Oxides of Nitrogen (NO_X);

The variation in NO_X emissions with BP for standard piston and SSCV piston operated engine with various blend proportion in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg) are shown in Fig. 5.9. Diesel has lower NO_X emission when equated with other fuels due to inefficient combustion. As the sesame biodiesel concentration increased in the diesel fuel the NO_X emissions increases due to increase in oxygen content of fuel as well as turbulence created by SSCV piston, by creating turbulence and enough oxygen provides complete combustion due to this exhaust gas temp increases. The NO_X emissions in the S20-D80 blend of SSCV piston are lesser than S10-D90 & S30-D70. If TBHQ additive added in the S20-D80 blend in the proportion of 500 & 1000mg then HC emissions decrease in both but by comparing additive proportion of both, the 500mg proportion NO_X emissions are lesser than 1000mg.

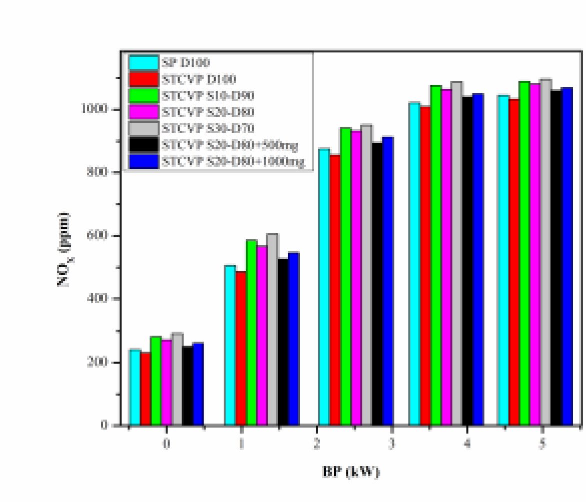

Fig. 5.9 Oxides of Nitrogen Variations

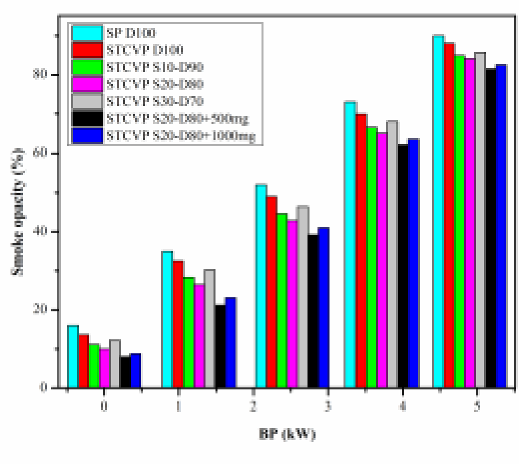

Fig. 5.10 Smoke Opacity Variations

By considering pistons the NO_X emissions of SSCV piston are lower than standard piston fueled with diesel. The NO_X emission of SSCV piston is 1.14% lesser than standard piston fueled with diesel at 4.9 kW BP (i.e. 1033 ppm & 1045 ppm) is observed. The outcome showed that the NO_X emissions of the biodiesel blend S20-D80+500mg operated with SSCV piston is 2.6 % higher than diesel fuel (i.e. 1060 ppm & 1033 ppm at 4.9 kW BP). By compare SSCV piston with S20-D80+500mg blend and standard piston with diesel, the SSCV piston has 1.43% higher NO_X emissions (i.e. 1060 ppm & 1045 ppm) at 4.9 kW BP. By comparing fuel blends of S20-D80+500mg is 2.39% lesser NO_X emissions than for SSCV piston (i.e. 1060ppm & 1081 ppm) at 4.9 kW BP. The NO_X emissions of the biodiesel blend S20-D80+500mg operated with SSCV piston are lesser than S10-D90, S20-D80, S30-D70 and S20-D80+1000mg).

5.3.4 Smoke opacity;

Fig. 5.10 shows the variation of smoke opacity with BP for SSCV piston and standard piston fueled with various blend proportions in diesel and also added additive to the best blend (i.e. Diesel, S10-D90, S20-D80, S30-D70, S20-D80+500mg and S20-D80+1000mg). Diesel has higher smoke opacity when compared with all other fuels. As the sesame biodiesel concentration is increased in the diesel fuel, the smoke opacity emissions decreases compare to diesel fuel due to increase in oxygen content of fuel. By considering fuel the smoke opacity emissions in the S20-D80 blend of SSCV piston is lesser compare to S10-D80, S30-D70 & Diesel fuel. If TBHQ additive added in the S20-D80 blend in the proportion of 500 & 1000mg then smoke opacity emissions further decrease in both, but by comparing additive proportion the 500mg proportion smoke opacity emissions are lesser than 1000mg. By considering pistons the smoke opacity emissions of SSCV piston is lesser than that of slandered piston irrespective of fuel. The minimum smoke opacity emissions of SSCV piston are 2.22% lesser than standard piston fueled with diesel at 4.9 kW BP (i.e. 88 ppm & 90 ppm) is observed. The outcome showed that the smoke opacity emissions of the biodiesel blend S20-D80+500mg operated with SSCV piston are 7.38 % lesser than diesel fuel (i.e. 81.5 ppm & 88 ppm at 4.9 kW BP). By comparing SSCV piston with S20-D80+500mg blend and standard piston with diesel, the SSCV piston has 9.44% lesser smoke opacity emissions (i.e. 81.5 ppm & 90 ppm) at 4.9 kW BP. The smoke opacity emissions of the biodiesel blend S20-D80+500mg operated with SSCV piston are lesser than Diesel, S10-D90, and S20-D80, S30-D70 and S20-D80+1000mg.

6 CONCLUSIONS

In this study, an experimental investigation is carried out to analyze the modification of combustion chamber by providing swirl enhancement grooves over the piston crown, on the performance, combustion and emission characteristics of biodiesel blend and results are compared with diesel. Based on the results, the following conclusions are drawn:

Based on experimental investigation on 4 stroke single cylinder DI-diesel engine powered successfully by various fuels such as D100, S10-D90, S20-D80,S30-D70, S20-D80+500mg & S20-D80+1000mg with two different pistons, viz., standard piston and SSCV piston, the outcomes of the optimization of the pistons for the blends of sesame biodiesel are presented here. Of the considered pistons, SSCV piston yielded superior performance characteristics of higher BTE and lower SFC for all ranges of load conditions with a blend of S20-D80+500mg of TBHQ additive as the fuel. The combustion characteristics for the blend of S20-D80+500mg with SSCV piston is preferable owing to EGT, NHRR & CHRR, this is due to enough oxygen and excess turbulence created by SSCV piston.

The emission characteristics for the S20-D80+500mg of TBHQ additive added fuel, SSCV piston is preferable owing to lower unburnt hydrocarbons, smoke emissions & carbon monoxide emissions. It may be due to the prevention of the stagnation of the rich mixture by directing the fuel spray towards the center and burn of emissions. In addition to this antioxidant additive to play an add-on role in the burning of the carbon deposits and act as an oxidizing as well as reducing agent to lower the oxides of hydrogen emissions. Better results are also obtained at peak pressure and during release attainment for SSCV piston with S20-D80+500mg of TBHQ additive.

Among the considered pistons and test fuels, for S20-D80+500mg of TBHQ additive and the piston preferred is SSCV piston. For the S20-D80+500mg of TBHQ additive fuel, the optimized piston suggested from current study is SSCV piston due to report of superior engine characteristics.

Nomenclature

Symbol	Abbreviations	Symbol	Abbreviations
HCC	hemispherical combustion chamber	BP	brake power
SP	standard piston	BTE	brake thermal efficiency
SSCVP	symmetrically stepped curved-v piston	P	cylinder pressure
SSCV piston	symmetrically stepped curved-v piston	SFC	specific fuel consumption
TBHQ	tert-butyl hydroquinone	EGT	exhaust gas temperature
D100	diesel 100%	NHRR	net heat release rate
S100	sesame biodiesel 100%	CHRR	cumulative heat release rate
S10-D90	fuel blend of sesame biodiesel 10% + diesel 90%	CO	carbon monoxide
S20-D80	fuel blend of sesame biodiesel 20% + diesel 80%	HC	hydrocarbons
S30-D70	fuel blend of sesame biodiesel 30% + diesel 70%	NO_X	oxides of nitrogen
S20-D80+500mg	fuel blend of sesame biodiesel 20% + diesel 80% + 500mg TBHQ	DI	direct injection
S20-D80+1000mg	fuel blend of sesame biodiesel 20% + diesel 80% + 1000mg TBHQ	mg	milligrams

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