SPRAY CHARACTERISTICS OF CHICHA OIL METHYL ESTER AND DIESEL FUEL IN A CONSTANT VOLUME CHAMBER

Ganesh Kumar. S[1], Dr. Raghu Palani[2], Dr. Pitchandi. K[3], Dr. Nallusamy. N[4]
PG Scholar, Internal Combustion Engineering, Sri Venkateswara College of Engineering, Sriperumbudur, Tamilnadu, India [1]
Asst Professor, Mechanical Engineering, Sri Venkateswara College of Engineering, Sriperumbudur, Tamilnadu, India [2]
Professor, Mechanical Engineering, Sri Venkateswara College of Engineering, Sriperumbudur, Tamilnadu, India [3]
Professor, Mechanical Engineering, SSN College of Engineering, Kalavakkam, Tamilnadu, India [4]

ABSTRACT

Use of unconventional fuels in Internal Combustion Engines plays an important role in both the Stand point of power as well as cutback of pollutant emissions into the environment. Fuel spray and atomization character play an significant role in the incineration, emission and mixture formation. The spray characteristics of fuel primarily depend on fuel injection pressure, fuel density, fuel viscosity, ambient pressure and temperature, combustion chamber pressure and injection duration. Among these fuel injection pressure is very significant parameter directly affecting spray formation. The main aim of the work is to study the spray parameter such as spray tip penetration, spray cone angle, spray width, spray volume, fuel injection velocity, and sauter mean diameter in a constant volume chamber at a range of injection pressure under non evaporating condition for biodiesel Chicha oil methyl ester (CCOME) and diesel fuel and non dimensional analysis of spray characteristics of tested fuel (CCOME and diesel fuel). High speed shadow graphic technique is used to trace the highly short-lived spray penetration process. The macroscopic spray properties are calculated with the help of ImageJ Software, which is an image processing technique.

Keywords: Biodiesel; Spray characteristics; Spray tip penetration; Spray cone angle; Spray volume;

I. INTRODUCTION

Spray structure is essential since spray shows how the air fuel mixture mixes in the engine combustion chamber. A spray that defectively atomizes fuel will lead to fuel-rich regions inside the cylinder, while a spray that is excessively dispersed will lead to a mixture that is in addition lean. Avinash Kumar Agarwal et al. [1] reported that effect of changeable injection pressures of the fuel and spray character was investigate in a single cylinder, direct injection engine fuel with biodiesel blends with pure diesel. The investigation results of spray tip penetration and spray area of neat diesel and biodiesel blends showed that raise in the fuel injection pressure result in an enhance in the spray tip penetration and spray area.

In this project experimental macroscopic spray characterization under high injection pressure and ambient pressure conditions was carried out with biodiesel. The results were compared with diesel fuel in order to understand the spray development process and air-fuel mixing process of biodiesel and its blend was studied by Yang et al. [2]. Jianfang et al. [3] studied that increase of needle opening pressure both the spray cone angle and the spray tip penetration of biodiesel increases, the atomization of spray improves, the ignition delay and duration of combustion becomes shorter and the peak pressure increases. The flow velocity of fuel increases with the increase in the needle opening pressure, so Reynolds number increases resulting in a bigger spray cone angle.

Reddy [4] study that the sauter mean diameter of Mahua, Neem and Silk worm papae oil were calculated by magnesium oxide (Mgo) coated technique. The outcome concluded that the SMD values of oils were found to be parallel as they were preheated and brought to the viscosity levels equal to that of diesel. The chicha oil obtainable a low acid value and a high content in fatty acids containing cyclopropenoid rings, ensuing in declining viscosity and density. The oil was transesterified and pyrolyzed to create the biodiesel and bio-oil. Some of the calculated physical and chemical properties of chicha oil, biodiesel and bio-oil are in suitable range for use as biofuel in diesel engines was investigated by Mangas et al. [5]

Kegl and Pehan [6] found that elevated viscosity of biodiesel affect atomization by raising the mean droplet size which increases the spray tip penetration, as an outcome the mixture formation and combustion get worse when biodiesel is used in its place of neat diesel fuel. This problem can be solving by joining together diesel with biodiesel, which will lessen viscosity. The other way to get better atomization is to inject biodiesel at higher pressures which will enhance the atomization progression by ever-increasing the dispersion of biodiesel spray.

Balasubramanian et al. [7] report that the blends of changing proportions of Sterculia Striata and diesel were analyzed and compared with the performance of neat diesel fuel. The BTE, BSFC, temperature of exhaust gas, emissions like HC, CO, Nox and smoke emissions were analyzed. The biodiesel emissions are reduced gradually. In this work, the spray and atomization characteristics were investigated for neat soybean biodiesel and 20% n-butanol biodiesel blend. The schlieren method was employed to measure macro spray characteristic and the PDIA technique were investigated by Jun Mo et al. [8].

Desmet et al. [9] studied the effect of varying injection pressure on the macroscopic spray parameters such as spray tip penetration, spray area and spray cone angle for a wide pressure range upto 2500 bar. The authors developed a measurement technique to found these characteristics quickly and reliably. The consequences ended it achievable to broaden the application fields of the short-term evolution law already suggested by various researcher scholars and established new laws for other spray characteristics (spray cone angle, spray area and spray volume).

Liquid fuel combustion requires atomization and penetration of the fuel in the appearance of a spray by means of spray atomizers such as injector. High quality of atomization is an important pre-requisite for good combustion. The injector injects the fuel in the form of a spray which undergoes breakup due to instabilities at the spray surface resulting in good atomization. The quality of atomization is characterized by the spray cone angle, spray width, liquid distribution in the spray pattern, spray penetration and sauter mean diameter. There is limited study on Chicha oil methyl ester (Sterculia striata) as feedstock for biodiesel production reported in the literature. Thus, the new finding of Chicha oil methyl ester is one of the possible oil crops for biodiesel production as a replacement of the fossils fuels. In the current study, biodiesel was prepared from the Sterculia striata. Properties of Chicha oil methyl ester were determined and their spray properties were studied on a Constant volume chamber and compared with the neat diesel fuel for suitability.

II. EXPERIMENTAL SETUP AND PROCEDURES

Biodiesel has become focus of alternative fuel research and application in recent years. There are some difference in physical parameters between biodiesel and diesel, and it is therefore necessary to study the spray characteristics of biodiesel in relation to its application in internal combustion engines. Diesel engine combustion is very complex (non homogeneous pre-mixed and diffusion) and is strongly controlled by the fuel spray injected into the combustion chamber. Due to stringent regulation on engine emissions studies in fuel spray formation and spray characteristics have been conducted. Injection pressure, viscosity and ambient density are the parameters which have significant influence on combustion and emission. The results of this work include information on the effect of injection pressure, ambient pressure, density and tip geometry.

In general, for the diesel fuel the high injection pressure or low ambient density allowed the spray to penetrate faster than low injection pressure or high ambient density. The spray significantly affects the ignition behaviour, performance, pressure rate, heat release, pollutant formation and exhaust emission formation.

The injection process is carried out in the constant volume chamber by varying injection pressure under evaporative conditions. The spray characteristics such as spray tip penetration, spray cone angle, spray width, and were found by using ImageJ Software.

Table 1. Properties of diesel with CCOME

PROPERTY	DIESEL	CCOME
Density at 30^o (Kg/m^3)	827	860
Viscosity at 40^o (mm^2/s)	2.87	4.64
Flash point (^{O}C)	56	160
Fire point (^{O}C)	66	172

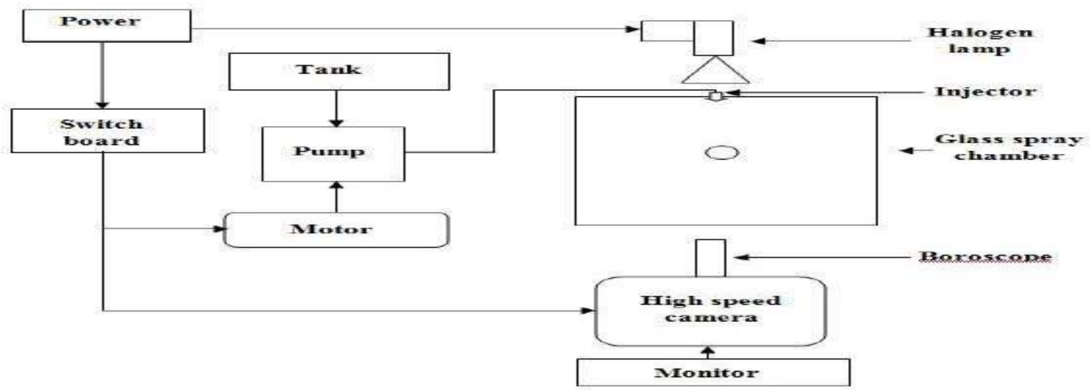

Fig. 1. Schematic diagram of the experimental layout

Table 2. Experimental Condition

Dimension of Glass Box	220 mm × 220 mm × 110 mm
Type of ignition	Compression ignition
Fuel injection	Solid/direct injection
Fuel injection system	Pump in line
Injection opening pressure	180, 200, 220, 240 bar
Nozzle hole diameter and number	0.3 mm and 3
Inlet temperature	37^{o}C
Inlet pressure	1 bar
Motor speed	1500 rpm

The properties of diesel and CCOME are listed in the Table 1 and the experimental layout, built using a glass spray chamber, is shown in fig. 1. The fuel was supplied from the fuel tank to the injector using a simple mechanical fuel pump with the help of motor and a fuel delivery pressure of 180-240 bars. All the experiments were carried out using a 0.25HP motor which was connected to a fuel injection pump. The experimental conditions are shown in Table 2. The spray process was examined with flash lamps as well as microscopic imaging techniques. The technique used for visualizing the liquid phase penetration was shadow graphic technique. The high speed camera with boroscope (Hawkeye Pro Rigid) was used to capture the spray structure. The high speed camera is set to take around 1250frames per second to capture the spray event with sufficient time resolution.

III. RESULTS AND DISCUSSION

The intention of the present study is to investigate the spray characteristics of the test fuels (diesel, CCOME) by varying injection pressure. Table.1 shows that liquid diesel has lower density and lower viscosity when compared to CCOME. Fuels with higher density and viscosity lead to higher spray tip penetration and poor atomization because of their higher inter-molecular forces. The spray characteristic of the fuel is shown in fig. 2 and the spray images of diesel, CCOME fig. 3.

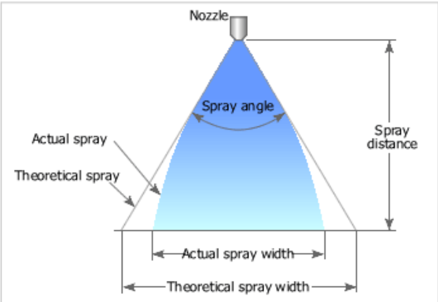

Fig. 2. Spray characteristics

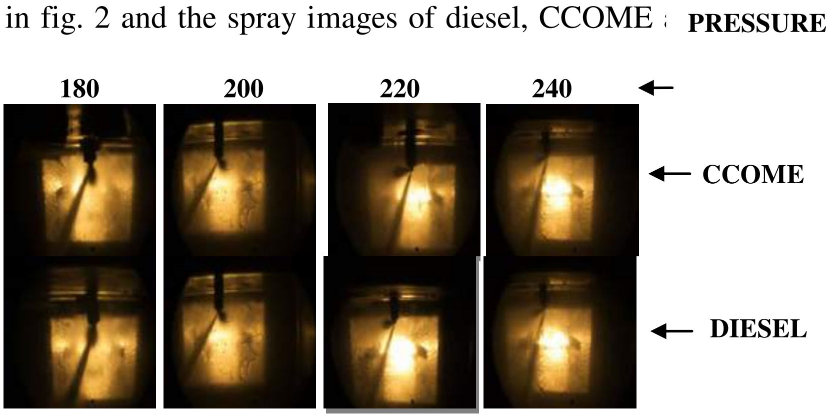

Fig. 3. Spray images of diesel and CCOME

i. Spray tip penetration

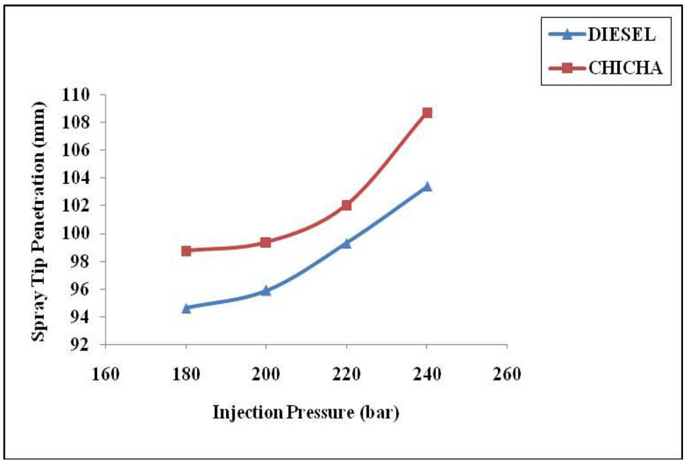

Fig. 4. Spray tip penetration for tested fuels at varying injection pressure

Fig. 4. shows the variation of spray tip penetration for Diesel and CCOME at varying injection pressures. The images of spray tip penetrations of diesel and CCOME showed almost similar variation. This is due to the elapsed time after start of injection from the nozzle and higher density and viscosity of biodiesel. The CCOME had longer spray tip penetration compared to diesel fuel due to its higher viscosity. The higher fuel density results in higher spray droplet velocity, higher fuel viscosity causes higher flow friction between the inner surface of the nozzle passage and fuel flow.

ii. Spray cone angle

Fig. 5. shows the variation of spray cone angle for Diesel and CCOME at varying injection pressures. The spray cone angle is defined as the angle formed by two straight lines that start from the exit of the nozzle orifice and tangent to the spray outline in a determined distance. Increasing the injection pressure raises the turbulence level into the orifice and then the dispersion of the spray at the exit of the injector. The spray of biodiesel start with smallest cone angle resulting from its highest viscosity, it is found that CCOME reduce the cone angle of the fuel spray due to increase in viscosity.

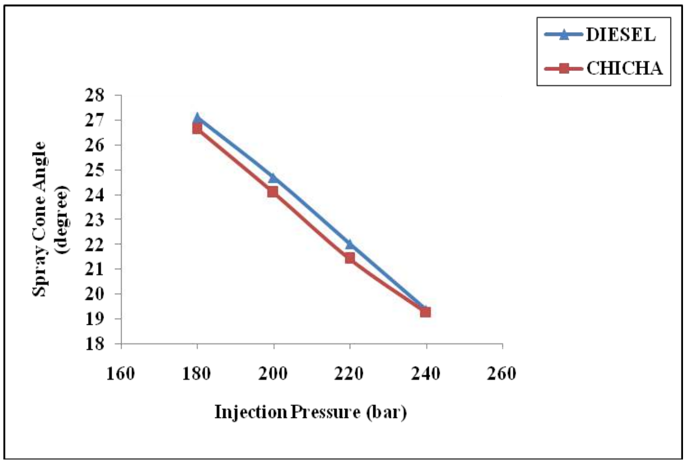

Fig. 5. Spray cone angle for tested fuels at varying injection pressure

iii. Spray width

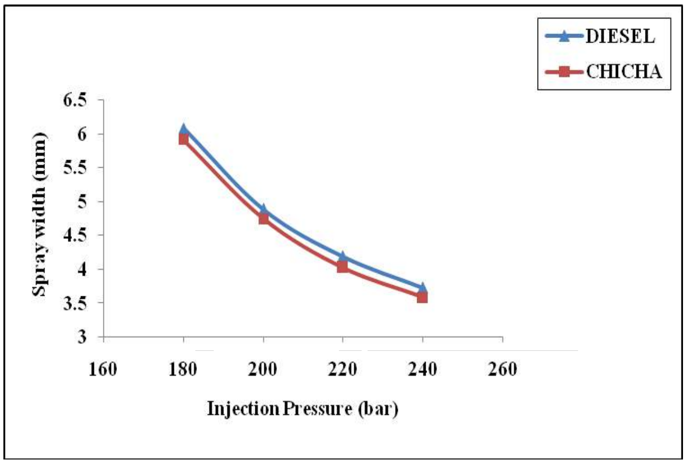

Fig. 6. Spray width for tested fuels at varying injection pressure

Fig. 6. shows the variation of spray width for Diesel and CCOME at varying injection pressures. The spray width is measured from a standard distance of 25mm from the nozzle tip. The spray width of a fuel generally increases for an increase in temperature and decrease in pressure. The spray width depends upon injection pressure and cone angle, because the width is horizontal cross sectional spread region of spray.

iv. Spray volume

Fig. 7. shows the variation of spray volume for Diesel and CCOME at different injection pressures. Fuel spray is assumed to consist of a cone and half a sphere, thus spray volume is described by the correlation suggested by Delacourt et al. [9], which is given in the below equation,

[illegible] → (2)

The spray volume can also be used to understand the fuel air mixing process in the combustion chamber. Larger spray volumes can be found at higher injection pressure. Compared with CCOME, Diesel fuel has smaller spray volumes due to their shorter spray penetration.

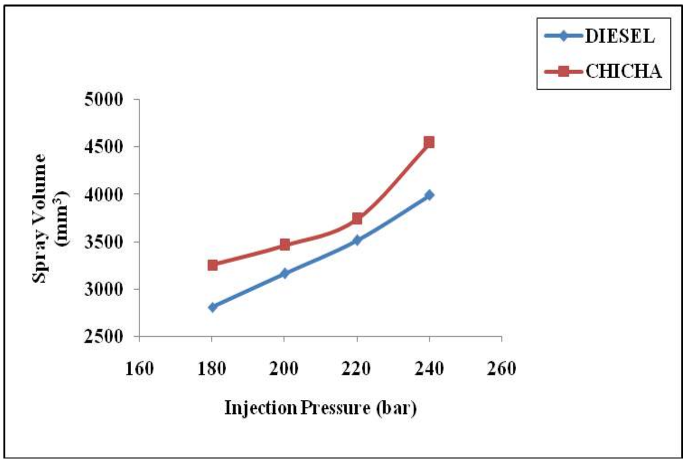

Fig. 7. Spray volume for tested fuels at varying injection pressure

v. Sauter mean diameter

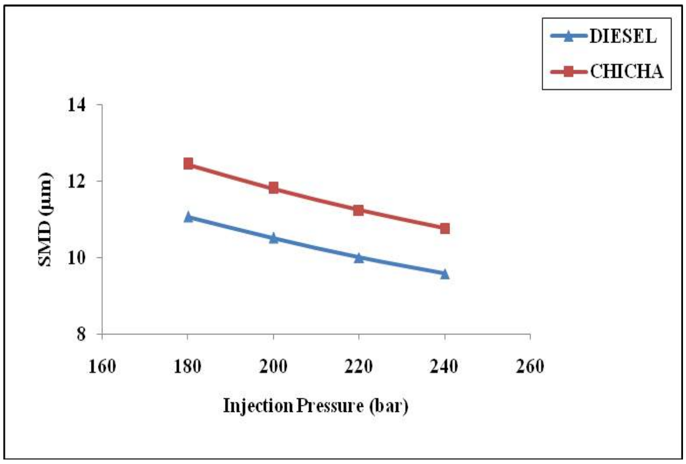

Fig. 8. Sauter mean diameter for tested fuels at varying injection pressure

The quality of the atomization of a mineral spray can be estimated on the medium diameter of the droplets. A determined medium diameter represents the equivalent diameter that characterizes the entire group of droplets of the spray. Thus, the theoretical drop diameter of the spray is calculated from the above equation, $\mathbf{SMD = 500\ D^{1.2}\gamma^{0.2} / V_{Inj}}$, Where,D – Diameter of orifice of nozzle (mm); γ – Kinematic viscosity of fuel (mm^2 / sec) V_{Inj}-Fuel injection velocity (m/s). From the Fig. 8. the SMD for CCOME is slightly greater diesel. The size of droplet depends upon fuel injection pressure and density, viscosity of the fuel and injection velocity.

IV. CONCLUSION

The experimental study of spray characteristics for Diesel and CCOME were studied in a spray chamber by varying injection pressure. The macroscopic spray properties were acquired from the images captured by a high speed video camera employing shadow-graphic and image processing techniques in a spray chamber.

Higher viscosity of CCOME fuels needs to overcome friction between the fuel and nozzle surface, which affects spray development than diesel fuel. It can be seen that spray volume are increased due to higher momentum of disintegrated small droplets at constant injection pressure, which induced the extension of spray region because of longer penetration of the spray tip. The smaller spray cone angle and spray width were observed larger for biodiesel due to its higher density and viscosity than diesel fuel. As the spray penetrates the droplets on the boundaries become smaller and diffuse easily generating a decreasing value of spray cone angle.

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