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Effect of Fuel Injection Pressure on Spray Characterization of Mahua Biodiesel Blend Using CRDI Injection System

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Abstract: In this study, the effect of fuel injection pressure on spray characterization of mahua biodiesel blend (B20) was visually analysed using CRDI fuel injection system. To analyse the spray characteristics, biodiesel blend fuel (B20) has injected at different injection pressures like 20, 30, 40and 50 MPa pressures. The fuel injection pressures and fuel injection durations were varied using electronic control module fitted with CRDI system. The spray structure of mahua biodiesel blend (B20) were recorded using a high-speed camera. For testing purpose one port of CRDI unit was connected with the solenoid fuel injector and other ports were closed. From the results obtained, it is clear that the spray tip penetration and spray cone angle were increased when the fuel injection pressure was increased from 20 to 50 MPa.
Keywords: Spray Characterization, CRDI, Diesel engine, Biodiesel, Fuel injection pressure.

I. INTRODUCTION

The over exploitation of Fossil fuels is becoming ever more threatened because of it is non-renewable. Lacks of energy supply and ecological pollution have increased with the increase of automobiles in the world. As a result, research on alternate fuel like biodiesel has drawn more attention. Biodiesel is a renewable and eco friendly, which has large, sources of raw materials. The production of biodiesel is carried out through many processes like transesterification, thermal cracking and catalytic cracking. In the transesterification process consist of break the triglycerides into monoglyceride with the use of alcohols. Biodiesel can be directly utilize or blended with diesel in different proportions, and they can be used in a diesel engine without any significant modification. The demand for petro based fuels and the stringent emission norms, many researchers have been found the new compression ignition (CI) approaches. For examples, gasoline compression ignition GCI, premixed charge compression ignition (PCCI), homogeneous charge compression ignition (HCCI), reactivity-controlled compression ignition (RCCI) and low-temperature combustion (LTC) [1]. The fuel spray characteristics like spray tip penetration (SIP) and spray cone angle (SCA) have a considerable influence on the combustion characteristics and exhaust emissions. In this work, the influences of the fuel injection pressure on the spray and atomization behaviour of mahua biodiesel were investigated.

II. SPRAY STRUCTURE

The fuel is introduced into the combustion chamber through the fuel injector nozzle with a high pressure differential between the common rail tube and the engine cylinder. The liquid fuel jet atomizes into small drops. The spray entrains air and spread out as the mass flow in the spray increases. The outer edge of the fuel droplets evaporates first, creating an air-fuel vapor mixture around the liquid containing core. At a low jet velocity, breakup of fuel droplet due to the unstable growth of surface waves caused by surface tension and results in fuels drops larger than the jet diameter. As the fuel jet velocity is increased, the force due to relative motion of the jet and the surface tension force and lead to a reduction in fuel drop diameter. Further increases in fuel jet velocity lead to the breakup in the atomization regime, where the breakup of the outer surface of the jet occurs at the nozzle exit and results in smaller diameter than the nozzle diameter. The high jet velocity is possible through the high pressure fuel injection using common rail fuel injection system. When the fuel is injected at high pressure, jet velocity increased and leads to the smaller diameter of fuel drops.
For jets in the atomization regime, the spray cone angle θ was found using the following relationship:

$$\tan\frac{\theta}{2} = \frac{1}{A}4\pi\left(\frac{\rho_g}{\rho_l}\right)^{\frac{1}{2}}\frac{\sqrt{3}}{6}$$

Where $\rho_l$and $\rho_g$are the liquid and gas densities in kg / m^3,
A is the nozzle hole area in m^2.
From the above correlation, it is clear that the nozzle hole area plays a major role in spray cone angle. In this work, six hole injector w used and it has very small nozzle hole area when compared with the conventional fuel injectors.

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III. MASS FLOW RATE THROUGH INJECTOR NOZZLE

The pressure upstream of the injector nozzle can be estimated, and assuming flow through nozzle is one-dimensional, incompressible and quasi-steady, the mass flow rate of fuel injected m_f through the nozzle:

$$m_f = C_d A_n \sqrt{2\rho_f (P_{inj} - P_{cyl})} \frac{\Delta\theta}{360N} \quad , kg/cycle$$

Where C_d is the coefficient of discharge,
A_n is the nozzle flow area in m^2,
ρ_f is the fuel density in kg / m^3,
(P_{inj}-P_{cyl}) is the pressure drop across nozzle orifice in Pascal,
$\Delta\theta$ is the injection duration in degrees crank angle and
N is the engine speed in RPM.

Generally, $P_{inj} >> P_{cyl}$. Thus, for a given injection rate and injection duration $\Delta\theta$ in crank angles, the injection pressure should vary with speed as,

$$P_{inj} \propto N^2$$

IV. SPRAY PENETRATION

The fuel spray penetrates across the combustion chamber has an important influence on better air-fuel mixing. Fuel injection pressure has a more significant effect on the spray penetration. Many correlations based on turbulent gas jet theory and experimental data have been proposed for fuel spray penetration. The correlation of spray tip penetration S versus pressure is given as:

$$S = 0.39 \left(\frac{2\Delta p}{\rho_l}\right)^{\frac{1}{2}} t$$

$$S = 2.95 \left(\frac{\Delta p}{\rho_g}\right)^{\frac{1}{4}} (d_n t)^{\frac{1}{2}}$$

Where Δp is the pressure drop across the nozzle in pascals,
ρ_l and ρ_g are the liquid and gas densities,
d_n is the nozzle diameter in metre and t is the time in seconds.

V. EXPERIMENTAL SETUP

The spray characteristics of the MME20 fuel blend was analyzed to study the influence of injection pressure on the atomization performance. A high-speed camera was used in this experiment. The camera featured a maximum electronic shutter exposure of 5 μs with a corresponding maximum resolution of 128 × 256. The captured images were downloaded to a computer connected to the camera. Because of the inclination of the nozzle holes, the central axis of the spray trajectory was towards the camera. The schematic diagram of the experimental set-up for spray photography is shown in Figure 1.

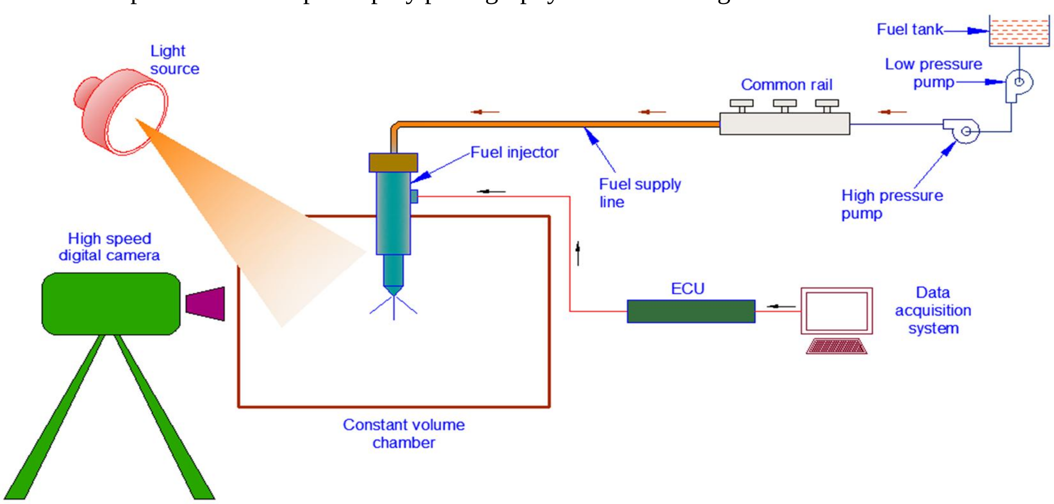

Figure 1 Schematic diagram of the experimental set-up for spray photography

VI. RESULTS AND DISCUSSION

The structure of the MME20 fuel spray has been observed with the set-up described. Tests were carried out for four different fuel injection pressures (20, 30, 40, and 50 MPa). On account of the data obtained, there exists a highly dense segment where the spatial distribution of the MME20 fuel blend is uniform pretty close to the nozzle exit. Further downstream of the nozzle, the high density portion starts to break up on the outer edge of the spray structure. This appeared as a fish-bone shaped structure of the spray. The pictures are taken 1.6 ms after fuel injection starts. As expected, an increase in penetration length resulted from an increase in injection pressure. Figure 2 shows the fuel injection from a 6-hole nozzle and Figure 3 shown maximum tip penetration of MME20 at different fuel injection pressures.As shown in the figure, the MME20 shows higher spray tip penetration at high injection pressure (50 MPa).

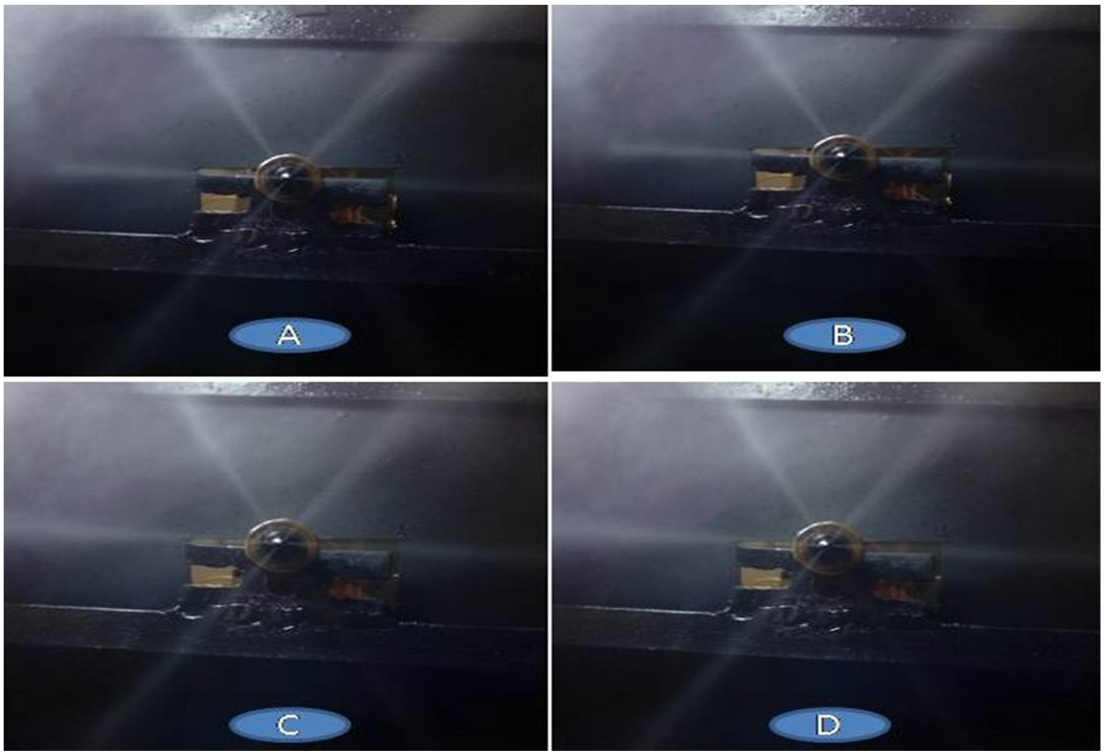

Figure 2 Fuel injection from 6-hole nozzle (A) at 20 MPa (B) at 30 MPa
(C) at 40 MPa (D) at 50 MPa

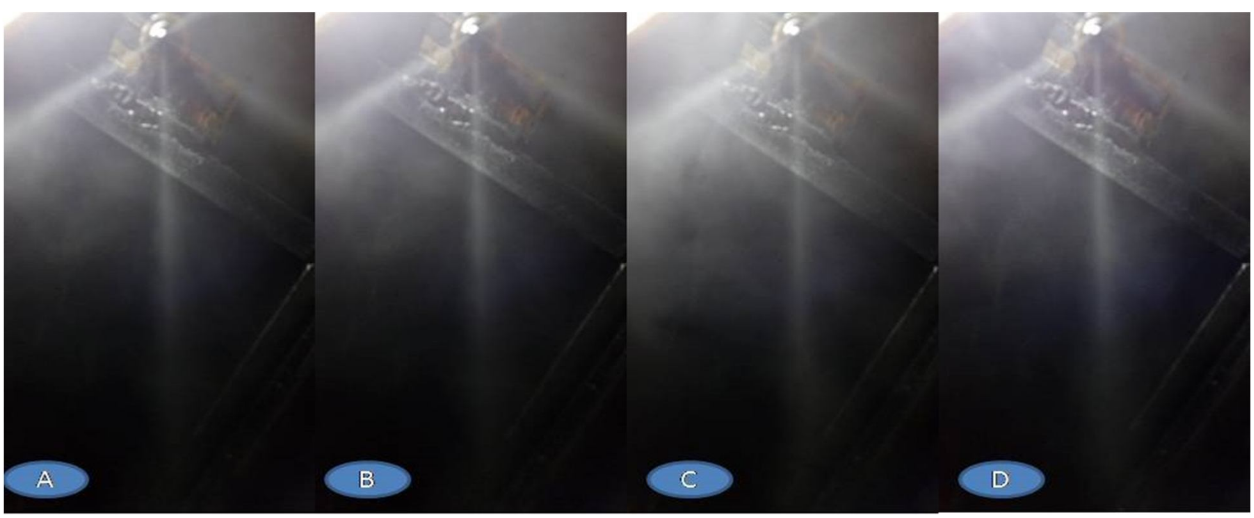

Figure 3 Images shown maximum tip penetration (A) at 20 MPa (B) at 30 MPa (C) at 40 MPa (D) at 50 MPa

VII. CONCLUSION

Fuel spray has a direct influence on performance, combustionefficiency, and emissions control. Better fuel atomization can promote through the proper mixing of fuel and air. Therefore, it is important to evaluate the spray tip penetration (SIP) and spray cone angle(SCA) of fuel. In this work, the analysis of macro spray characteristics like SIP and SCA were visually analysed through high speed camera.The obtained resultsshow that, the SIP and SCA both increase with increasing the fuel injection pressure from 20 to 50 MPa.The Maximum injection pressure of 50 MPa shows the optimum SIP and SCA.

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