EXPERIMENTAL INVESTIGATION ON FUEL SPRAY PARAMETERS AND CHARACTERISTICS OF DIESEL AND BIO-DIESEL BLEND

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ABSTRACT :

Currently, emission norms are very stringent due to global warming and pollution all over world, in order to reduce these emissions the current research is going on in alternative fuel. In this way the study of fuel spray characteristics is a vital one, which influences the emission, combustion and mixture formation. The spray characteristics of fuel primarily depend on fuel injection process, fuel density, viscosity, ambient pressure and temperature. The main aim of the work is to study spray parameters and injection pressure at ambient conditions for Neem oil blend (NB20) and Chicha Oil Methyl Ester (CCOME) fuelled in a spray chamber under non evaporating condition. The Macroscopic spray characteristics, such us spray tip penetration, spray cone angle, spray area, were found by Image processing technique (ImageJ software). It was observed that increasing injection pressure would improve the spray tip penetration and spray area, due to this reason a decrease in spray cone angle and for NB20 and CCOME were observed when compared to diesel. The effect of fuel properties on near nozzle morphology was calculated. The spray formation was prolonging and narrower spray cone angle is observed for NB20 and CCOME as compared to diesel. This work also investigates spray atomization and penetration of different fuels with diesel.

Key words: Injection pressure; Spray tip penetration; Spray cone angle; Spray area.

INTRODUCTION

In the current situation, Petroleum based fuels are being replaced by alternative fuel because of their uniqueness, especially CCOME, KOME and Rape seed methyl ester. In favor of, to meet the emission norms and reducing the fuel consumption and numerous experiments have been done on spray characteristics, combustion and emission in Direct Injection (DI) Diesel engines [1, 2 and 3]. Many research papers have been studied and report the various effect of macroscopic spray character such as spray penetration, spray cone angle, spray area, spray width and shape factor. Imminent study of fuel spray of bio-diesel in Compression Ignition (CI) engines aims to lower the Unburnt Hydrocarbon (UHC), oxides of Nitrogen (NO_x) and particulate Matter (PM) and enhance the overall efficiency in terms of complete combustion.

To prolonging injection along with injection duration were necessary to pay off the low calorific value and also reduction in radiation due to biodiesel soot source to increase in NOx (Chao, 2008). Boggavarapu [7] reviewed the effect of fuel properties on the atomization process for both biofuels and fossil fuels and summarized that biodiesel sprays showed faster penetration and narrower spray plume angles and larger droplet sizes as compared to diesel. Abdul Adam bin Abdullah [4] studied the effect of kinematic viscosity of straight vegetable oil on fuel injection spray characteristics using constant volume high pressure spray chamber. Straight vegetable oil spray tip penetration measured shortest and narrow cone angle compared with biodiesel and diesel spray, these are due to the high level of kinematic viscosity inside straight vegetable oil compared to biodiesel and diesel fuel. Straight vegetable oil at high ambient temperature produce similar spray structure as diesel spray due to kinematic viscosity level of straight vegetable oil decreased with increased of fuel temperature. The diesel engine combustion process is directly influenced by spray characteristics. In many research papers convey their spray characteristics studies on bio-diesel and comparison of spray character for rapeseed oil, soya bean oil, palm-oil, waste cooking oil and diesel. The main focus of the paper to experimental investigation of fuel spray character of bio-diesel and diesel along with various injection pressures under ambient pressure and temperature condition for non-evaporating spray.

EXPERIMENTAL SETUP

The experimental setup was shown in fig. 1. The setup consists of a spray chamber (200mmx90mmx220mm), fuel injection system, high speed video camera Fastec IL3-100L, Fastec imaging and data acquisition system. In this experiment, the spray characteristic was observed from a constant volume chamber along with fuel injection system and highly illuminated light source. The spray chamber made up of glass. The fuel injection system having electric motor (0.25hp), fuel pump (Jerk type) and fuel injector. A high speed video camera name viz, Fastec Motion to capture the image and it will be further processed and analyzed by using (ImageJ software). In this work, the starting of injection pressure was studied at 4 different conditions at 180,200,220,240 bar. The spray images were captured at a frame rate of 150fps with resolution of 800×600. The Shadowgraphy technique is applied, where the light source is placed opposite to the camera. A 1000W halogen lamp is used to illumine for clear and visible images. Table 1 shows the properties of tested fuels.

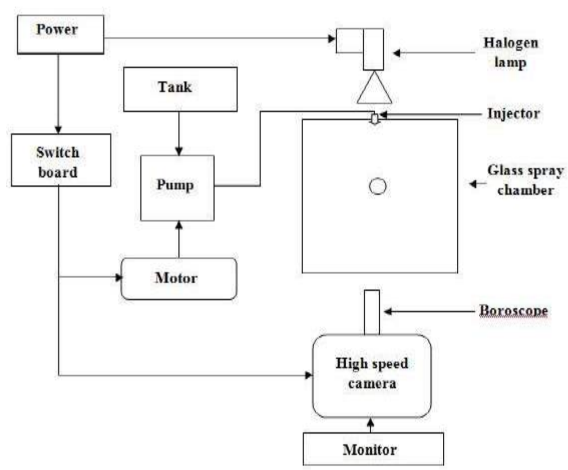

Figure 1. Schematic Diagram of experimental setup

Figure 2. Actual Picture of the experimental setup

PROPERTY	DIESEL	CCOME	NEEM OIL(NB20)
Density (at 30℃) (kg/m^3)	827	860	837.52
Viscosity (at 40℃) (mm^2/s)	2.87	4.64	3.64
Surface Tension (N/m)	0.022	0.029	0.027
Flash Point (℃)	56	160	152
Fire Point (℃)	66	172	159

Table 1. Properties of the fuels used

EXPERIMENTAL CONDITIONS

Dimension of the combustion chamber	200mm×90mm×220mm
Fuel injection	Solid/direct injection
Injection opening pressure	180, 200, 220, 240 bar
Nozzle hole diameter and number	0.3 mm and 3
Inlet temperature	32^{o}C
Combustion chamber pressure	1 bar
Motor speed	1420 rpm

RESULTS AND DISCUSSION

The aim of the present study to investigate the spray characteristics of test fuels by varying injection pressures. Fuel having high viscosity have higher spray tip penetration length and spray area such us CCOME, NB20 and diesel, while decrease in the spray cone angle. However droplet distribution and liquid breakup length are small and depends on the density of fuel. Fuel having high density and spray atomization and higher spray tip penetration are because of fuel high inter molecular spaces. Figure 3 shows the spray image of Diesel, CCOME and NB20 respectively at 180 bar injection pressure.

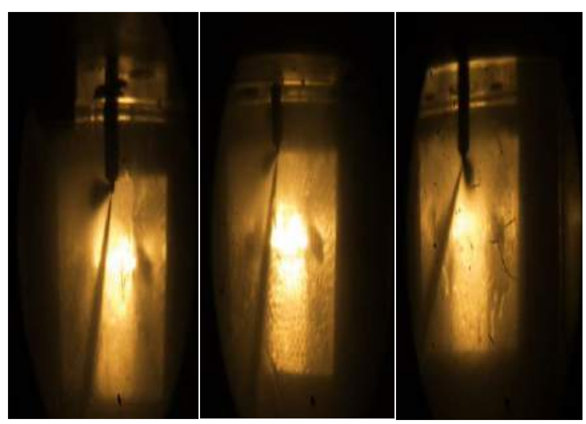

Figure 3. Snapshots of the fuel spray of Diesel, CCOME and NB20 at 180 bar pressure

SPRAY TIP PENETRATION: Spray tip penetration is the maximum penetration length extended from the spray tip after the start of injection. It is found using 'line' command in ImageJ software. The spray tip penetration increased with increase in injection pressure, due to less atomization, high surface tension and low fuel vaporisation of biodiesel blend as shown in Figure 4. The spray tip penetration of diesel was lower compare to CCOME and NB20 due to viscosity and density.

SPRAY CONE ANGLE: The spray cone angle is defined as the largest angle formed by two straight lines from the nozzle tip to the spray boundary. While increase in injection pressure will increase the spray evaporation and its velocity, therefore, decreasing the spray cone angle. At low pressure, the angle of biodiesel is lower when compared to diesel. This is due to high viscosity of the biodiesel. Also, the effect of increased friction between biodiesel and the nozzle surface is eliminated by high injection pressure. Figure 5 shows the graph between the injection pressure and spray cone angle.

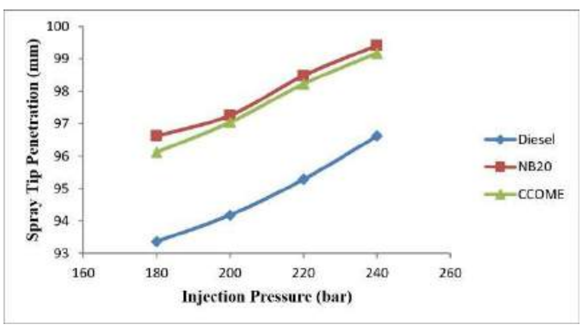

Figure 4. Injection Pressure vs Spray Tip Penetration

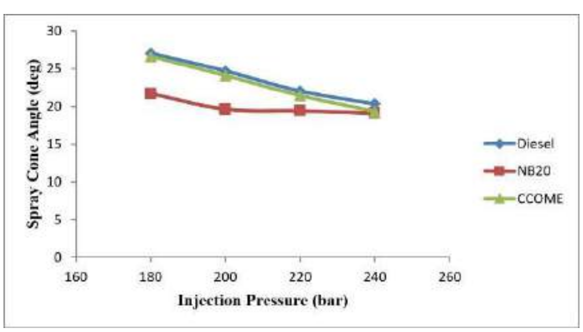

Figure 5. Injection Pressure vs Spray cone Angle

SAUTER MEAN DIAMETER (SMD): It is defines as the average diameter of a fuel droplet after injection process. The unit is µm. The better tendencies are investigated using the SMD correlation,

$$SMD = 6156\ (\upsilon^{0.385}\ \sigma^{737}\ \rho_f^{0.06}\ \Delta P^{-0.54})$$

where,

ρ_f – Density of fuel (kg/m^3)

σ – Surface tension of fuel in N/m

ΔP – Pressure difference

(injection pressure – chamber pressure) in bar

υ - Kinematic viscosity of fuel in m^2/s

The higher viscosity, density and surface tension are the reasons for higher SMD values of biodiesel when compared to diesel. As the injection pressure increases, the SMD values of all the fuels decreases which leads to better atomization. The graph between injection pressure and SMD is shown in Figure 6.

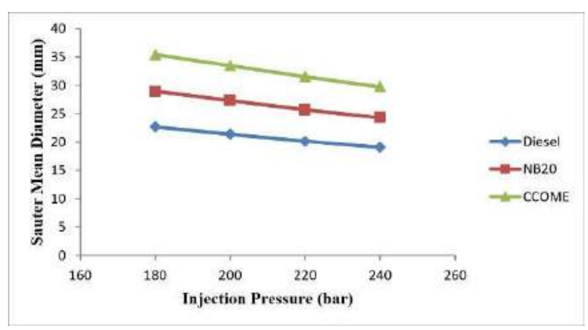

Figure 6. Injection Pressure vs Sauter Mean Diameter (SMD)

SPRAY BREAKUP REGION: Reynolds number and Weber number describe the spray breakup region of fuels. The relation between the inertia force and viscous force is known as Reynolds number. The relation between the superficial tension force and inertial force is known as Weber number. Both the numbers increase for the fuels with increase in injection pressure due to larger viscous forces and smaller inertia forces. This gives a large spray momentum for the CCOME and NB20. In other words, the numbers increase for the diesel. Figure 7 and 8 shows the graph between the injection pressure and Reynolds number (R_e) and Weber number (W_e) respectively. The formulae are shown below,

$$R_e = (\rho_f \, . \, d_{nozzle} \, . \, V_{inj})/\mu$$

$$W_e = (\rho_f . \, V^2_{inj} . \, d_{nozzle})/\sigma$$

where,

ρ_f = Density of the fuel in kg/m^3

V_{inj} = Injection velocity in m/s

d_{nozzle} = Diameter of the nozzle in m

μ = Kinematic viscosity in m^2/s

σ = Surface tension of fuel in N/m

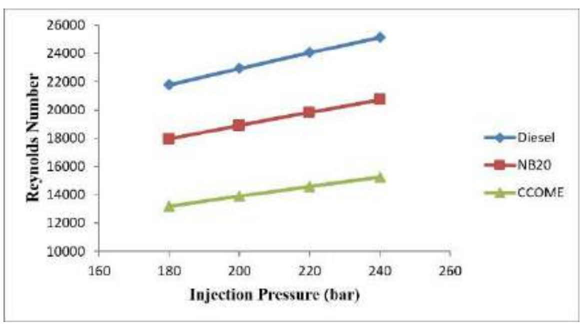

Figure 7. Injection Pressure vs Reynolds number

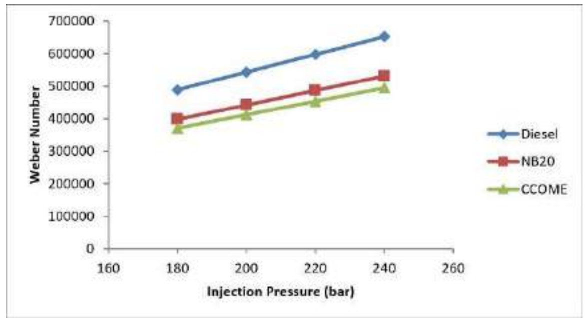

Figure 8. Injection Pressure vs Weber number

SPRAY AREA: Spray area is determined by drawing along the boundary of the spray pattern using the 'freehand' drawing tool in ImageJ software. The graph between injection pressure and the spray area is shown in Figure 9. It can be observed that NB20 and CCOME has larger spray area when compared to that of diesel at a given pressure. This is due to high physical properties of CCOME and NB20. It can also be concluded that upon increasing the pressure, the spray area of the fuels get increased.

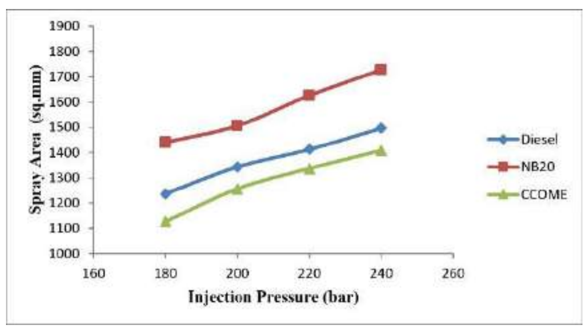

Figure 9. Injection Pressure vs Spray Area

INJECTION VELOCITY: The injection velocity depends on the properties of the fuel. NB20 and CCOME have higher viscosity and density when compared to diesel. The graph between the injection pressure and injection velocity is illustrated in Figure 10. It can be observed that diesel has higher injection velocity than CCOME and NB20. It can be concluded that higher pressure means higher injection velocity which in turn results in better atomization of the fuel. Injection velocity can be formulated as,

$$V_f = (2(P_{inj} - P_c)/\rho_f)^{1/2}$$

where,

V_f = Injection velocity in m/s
P_{inj} = Injection Pressure in bar
P_c = Chamber Pressure in bar
P_f = Density of the fuel in kg/m^3

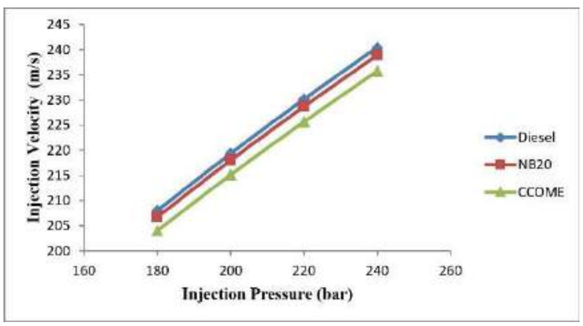

Figure 10. Injection Pressure vs Injection Velocity

CONCLUSION

The spray characteristics of biodiesel (CCOME and NB20) and diesel of constant volume chamber under various injection pressures were performed by using optical technique. The spray tip penetration and spray area for biodiesel are increasing due to high viscosity, density and volatility. The spray cone angle decreases because of increasing in injection pressure. The SMD values of the fuels decrease with increase in injection pressure which leads to better atomization. Due to high physical properties of CCOME and NB20, the spray area is larger for both the fuels when compared to diesel. Also, at higher injection pressures, the Reynolds number and Weber number increases for all the fuels with diesel having the highest value among them. The injection velocity of diesel is higher due to its lower density and viscosity when compared to that of CCOME and NB20. Thus, the effect of injection pressure on spray tip penetration suggests that increasing the injection pressure of tested fuels is necessary to ensure maximum air contact with fuel is achieved.

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REFERENCES

1. Avinash Kumar Agarwal, Vipul H. Chaudhary, Spray characteristics of biodiesel/blends in a high pressure constant volume spray chamber, Experimental Thermal and Fluid Science, 42, 2012, 212–218.

2. Chao He, Yunshan Ge1, Jianwei Tan and Xiukun Han, Spray properties of alternative fuels: A comparative analysis of biodiesel and diesel, Int. J. Energy Res., 32, 2008, 1329–1338.

3. Seunghun Choi, Youngtaig Oh "The spray characteristics of unrefined biodiesel" Renewable Energy 42 (2012): 136 139.

4. Abdul Adam Bin Abdullah (2010). Study on spray characteristics of straight, vegetable oil. National Conference in Mechanical Engineering Research and Postgraduate Studies (2nd NCMER 2010), pp. 520-526.

5. Ghurri, A., Kim, J. D., Kim, H. G., Jung, J. Y. & Song, K. K. (2012).The effect of injection pressure and fuel viscosity on the

spray characteristics of biodiesel blends injected into an atmospheric chamber. Journal of Mechanical Science and Technology, Vol. 26, No. 9, pp. 2941-2947.

6. Roisman, I.V.; Araneo, L.; Tropea, C. Effect of ambient pressure on penetration of a diesel spray. Int. J. Multiph. Flow 2007, 33, 904–920.

7.Boggavarapu, P.; Ravikrishna, R.V. A review on atomization and sprays of biofuels for IC engine applications. Int. J. Spray Combust. Dyn. 2013, 5, 85–121.