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Study of Spray Breakup Regimes of Preheated Biodiesel Fuel

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***Abstract:* -- Spray characteristics such as spray cone angle, Sauter mean diameter (SMD) and spray tip penetration greatly influences the combustion and emission characteristics of diesel engines. The spray characteristics mainly depend on fuel viscosity, injection pressure, density of fuel, ambient pressure and temperature. This study focusses on the spray break up regimes and the effect of injection pressure and fuel temperature on the spray characteristics in a constant volume chamber using image processing techniques on Diesel and Cottonseed Oil Methyl Ester (COME). The Reynolds number, Weber number and Ohnesorge number were used to capture the primary forces including inertial force and surface tension. The main objective of this work is to obtain the non-dimensional correlations for Sauter mean diameter, spray cone angle and spray tip penetration with extensive insight into spray break up regions and atomisation process.**

***Index Terms*— spray characteristics, image processing techniques, non-dimensional correlations, spray tip penetration.**

I. INTRODUCTION

A fuel is any material that can be made to react with other substances so that it releases chemical or nuclear energy as heat or to be used for work. The concept was originally applied solely to those materials capable of releasing chemical energy but has since also been applied to other sources of heat energy such as nuclear energy (via nuclear fission and nuclear fusion). The heat energy released by reactions of fuels is converted into mechanical energy via a heat engine. Other times the heat itself is valued for warmth, cooking, or industrial processes, as well as the illumination that comes with combustion. Fuels are also used in the cells of organisms in a process known as cellular respiration, where organic molecules are oxidized to release usable energy. Hydrocarbons and related oxygen-containing molecules are by far the most common source of fuel used by humans, but other substances, including radioactive metals, are also utilized.

Fossil fuels were rapidly adopted during the industrial revolution, because they were more concentrated and flexible than traditional energy sources, such as water power. They have become a pivotal part of our contemporary society, with most countries in the world burning fossil fuels in order to produce power. Currently the trend has been towards renewable fuels, such as biofuels like alcohols.

A literature review on properties and characteristics of sprays, cottonseed oil methyl ester and non-dimensional analysis of sprays has been carried out. The important observations are highlighted here.

Faeth, et al(1995) studied the structure and breakup properties of sprays. Through their studies, they concluded that some understanding of turbulent primary breakup has been achieved but more information about aerodynamic primary breakup is needed to address practical spray combustion processes.

Nurun Nabi, et al(2008) investigated different parameters for the optimisation of biodiesel production in the first phase of study. While in the next phase of the study, performance test of a diesel engine with neat diesel fuel and biodiesel mixtures were carried out. Through their study, the effect of cotton seed oil methyl ester on engine performance and emission characteristics were understood.

Wei Zeng, et al(2012) quantified the macroscopic spray characteristics using dimensionless analysis by examining the role of dominating forces associated with liquid-jet breakup. This analysis yielded correlations that provide important insight into the spray breakup and atomisation process.

Ainul Ghurri, et al (2012) studied the effect of injection pressure and fuel type on the spray tip penetration and spray cone angle of spray injected into the atmospheric chamber. The result showed that the biodiesel content increased the spray tip penetration and increased the spray cone angle. The correlation of spray tip penetration was expressed for each region before and after breakup time in terms of injection pressure, fuel viscosity and time after start of injection.

2.EXPERIMENTAL-SETUP AND PROCEDURE

The experimental setup for visualising the spray comprises of the following components:
The figure given below shows the experimental setup for investigating the macroscopic spray characteristics of biodiesel. Fuel injector is mounted on top of the constant volume chamber. The fuel injection system used in the spray experiments is identical to the one used in the production grade constant speed single cylinder engine. The injector is a simple mechanical fuel injector with delivery opening pressure set at 180 bar and 200 bar. Fuel injector was connected to the fuel pump via the high pressure line. The spray process is examined with flash lamps as well as microscopic imaging techniques

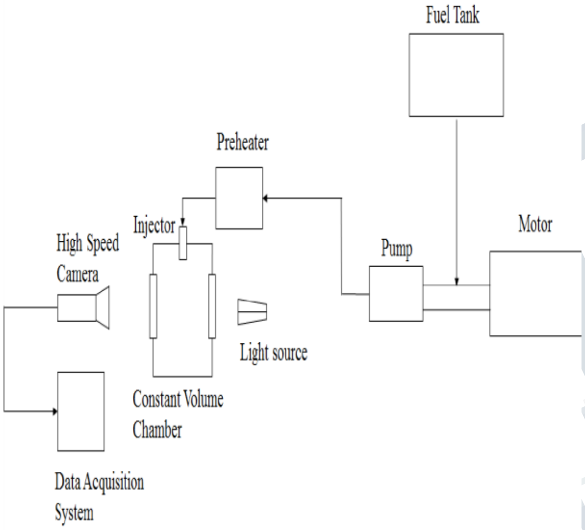


FIG 1: SHOWS THE EXPERIMENTAL SETUP

The apparatus is arranged as given in the experimental setup. The injection pressure is set to the required value using the pressure testing equipment. It is mounted over the spray chamber as given in fig.1.

The preheated fuel is then fed into the tank and the pump is used to transfer the fuel from the tank to the injector. The injector sprays the fuel at the pre-set pressure into the spray chamber.

The FASTEC high speed camera is used to capture the images using the Shadowgraphy technique (classical visualisation technique). Among the captured images, the best image is selected manually. The best image is then analysed using Image J software.

The spray parameter readings namely spray cone angle and spray tip penetration are determined. The aforementioned procedure is followed for fuels mentioned in Table-2 with the measurements taken at 180, 200 and 220 Bar were the fuel temperature is varied between 40^{0}C, 60^{0}C and 80^{0}C at each pressure.

FOR 180 BAR

Temperature T(□c)	Spray tip penetration (s) (mm	Spray Cone Angle(θ) (Degree)	Sauter Mean Diameter (SMD)(μm)
40	56.18	13.654	13.519
60	54.702	14.948	12.334
80	52.772	15.474	11.756

FOR 200 BAR

Temperature T(□c)	Spray Tip Penetration (S)(mm)	Spray Cone Angle(θ) (Degree)	Sauter Mean Diameter (SMD)(μm)
40	56.558	13736	12.822
60	53.938	15.14	11.698
80	49.984	15.7482	11.151

FOR 220 BAR

Temperature T(□c)	Spray Tip Penetration (S)(mm)	Spray Cone Angle(θ) (Degree)	Sauter Mean Diameter (SMD)(μm)
40	50.2	15.77	12.2225
60	49.29	17.21	11.1516
80	47.35	19.08	10.6290

TABLE-2: EXPERIMENTAL READINGS OBTAINED AFTER ANALYSIS USING IMAGE J SOFTWARE

3.RESULT AND DISCUSSION

Graphs are plotted with the spray angle, spray tip penetration and Sauter mean diameter along the y-axis and Reynold’s number, Weber’s number and Ohnesorge’s number along x- axis. From the graphs, further inferences and values are obtained for non-dimensional analysis.

The coefficients of the linear equations obtained can be combined with respect to the spray tip penetration (s) by using the following mathematical computations :

Let the linear equations be taken as:

$y = m_1x + c_1$; $y = m_2x + c_2$; $y = m_3x + c_3$

The three equations are added :

$3y = (m_1 + m_2 + m_3)\, x + (c_1 + c_2 + c_3)$

Assuming that we are working with linear equations pertaining to the spray tip penetration and Reynold’s number at all experimental conditions (i.e. 180 bar, 200 bar and 220 bar), we have three equations . In these equations, ‘x’ and ‘y’ indicate the x-axis and y-axis of their corresponding graphs.

Therefore, substituting
$x = \log(Re)$; $y = \log(s)$;also let $c_n = \log(k_n)$

$\Longrightarrow 3\log(s) = (n_1 + n_2 + n_3)\log(Re) + (\log k_1 + \log k_2 + \log k_3)$

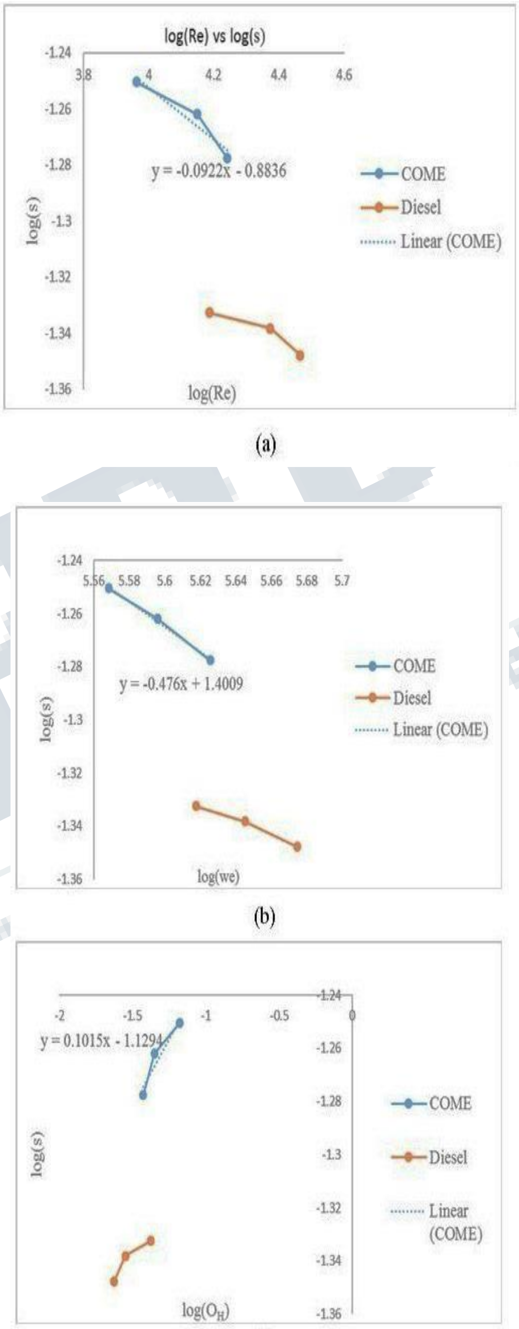
$\Longrightarrow \log s^3 = \log\,[(k_1 \,.\, k_2 \,.k_3)\, Re\, ^\wedge (n_1 + n_2 + n_3)]$

Taking antilog and further computing we get:

$s = (k_1 \,.\, k_2 \,.k_3)^{1/3} .\, Re^{\,(n1+n2+n3)}$

This equation represents the generalised form for the given set of linear equations. Similarly, generalised form for cone angle and Sauter mean diameter are each obtained separately for corresponding Reynold’s, Weber’s and Ohnesorge’s number.

FOR 180 BAR

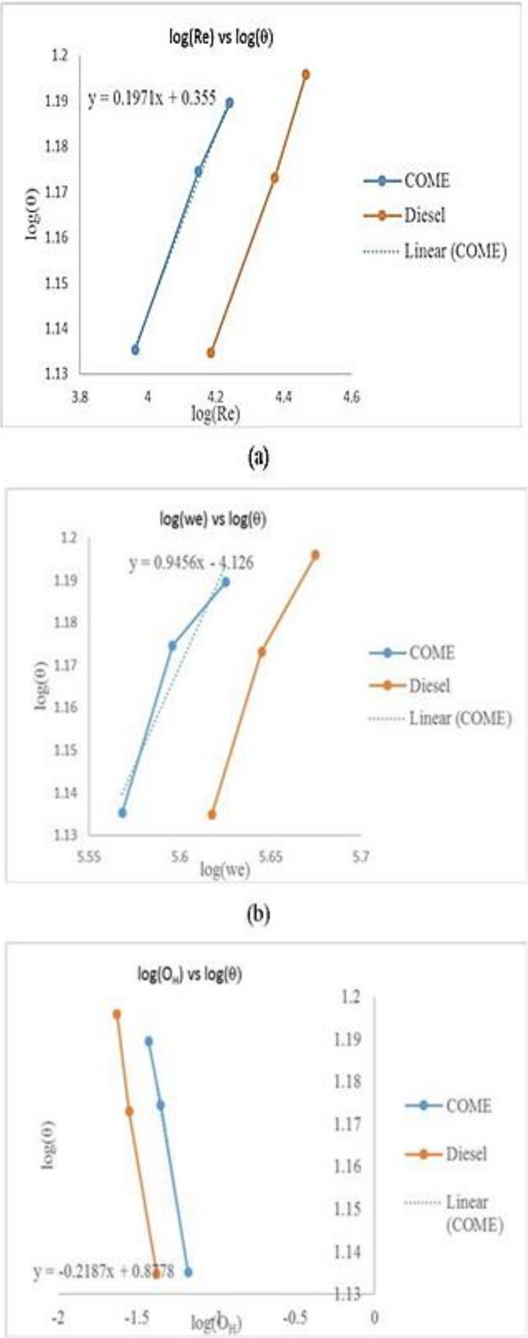


(a)

(b)

(c)

Fig 3.1 (a, b, c) – Graphs and equations for spray tip penetration (s).

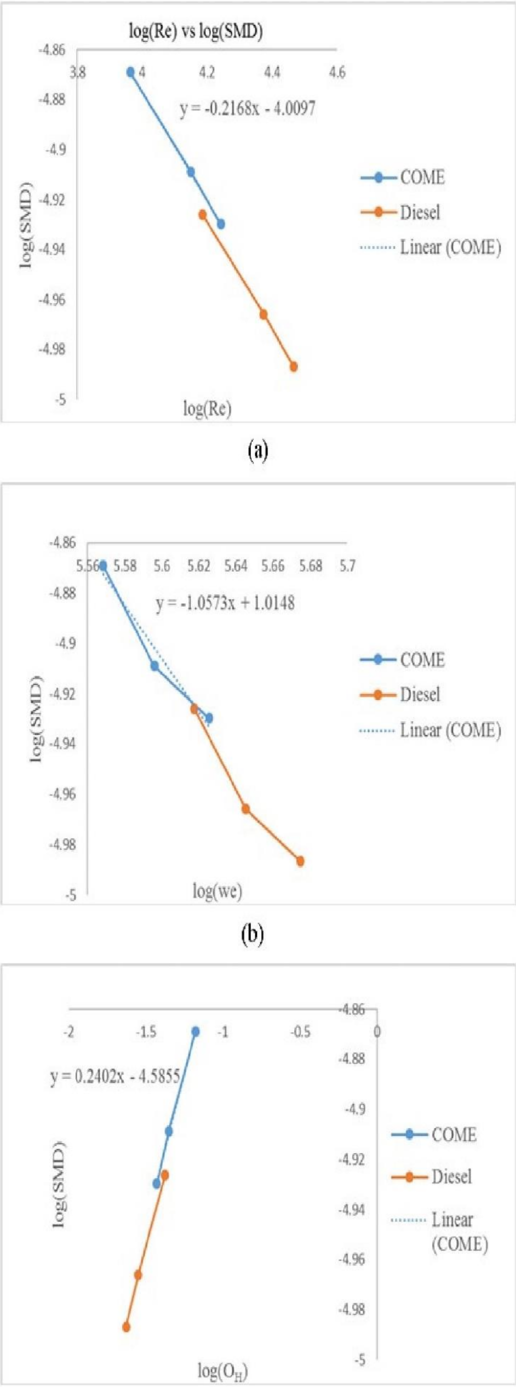


(a)

(b)

(c)

Fig 3.2 (a, b, c) – Graphs and equations for spray cone angle (θ).



(a)

(b)

(c)

Fig 3.3 (a, b, c) – Graphs and equations for sauter meter diameter (SMD).

From many referenced research works in spray break up, it can be understood that there are three major break-up types that affect the break-up models and in turn affect the atomisation process. They are as follows:

- Bag break-up
- Sheet stripping (or) boundary stripping break-up
- Catastrophic break-up

Other break-up regimes are not relevant in a typical spray forming process. This can be seen by plotting Iso-Weber numbers in a relative velocity vs. initial droplet size diagram. One can see that these remaining break- up regimes will only occur for very large droplets exposed to a high relative velocity. According to Lee and Reitz (2001), and many previous researchers, the breakup process is primarily influenced by the value of the Weber number in all three breakup regimes.

4.CONCLUSION

- The macroscopic spray characteristics such as spray tip penetration, spray cone angle and Sauter mean diameter are determined at the pressure and temperature conditions: 180-220 bar, 40-800C. The effect of fuel viscosity, fuel temperature, fuel density and injection pressure on spray characteristics in a constant volume chamber are also studied successfully.
- The non-dimensional correlations for spray tip penetration, spray cone angle and Sauter mean diameter were successfully obtained by performing various mathematical computations.
- These equations and further review of various research papers have provided an extensive insight into the spray droplet break up and atomisation process, which have, in turn, helped further the understanding of the influence of use of biodiesel on engine efficiency.

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6.REFERENCES

1. J. Dernotte, C. Hespel, S. Houille, F. Foucher & C. Mounaïm-Rousselle (2012), 'Influence of fuel properties on the diesel injection process in non-evaporating conditions', Atomization and sprays , Vol. 22, pp:462-492.

2. G.M. Faeth, L.P. Hsiang, P.K. Wu (1995), 'Structure and breakup properties of sprays', Elsevier - International Journal of Sprays, Vol. 21, pp. 99-127.

3. Gerhard Knothe (2005), 'Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters', Elsevier - Fuel Processing Technology, Volume 86, Issue 10, pp:1059-1070.

4. G. Knothe, J Krahl, J Van Gerpen (2005), 'The biodiesel handbook', AOCS Press, pp:268-286. Mikhael Gorokhovski and Marcus Herrmann

5. (2008), 'Modeling and primary atomisation', Annual Review of Fluid Mechanics, Vol.40:343-356.

6. Rasmus Gjesing, Jesper Hattel and Udo Fritsching (2009), 'Coupled atomisation and spray modelling in the spray forming process using OpenFOAM', Engineering Apps. in computational Fluid Mechanics, Vol.3, No.4, pp.471-486.

7. Prof.Rolf D. Reitz, 'Reciprocating Internal Combustion Engines', 2012, PricetonCEFRC.

8. Simón Martínez-Martínez, Fausto Sanchez, Vicente Bermudez and J. Manuel Riesco-Avila (2010), 'Liquid sprays characteristics of diesel engines', Fuel Injection, InTech Europe.

9. Zeng. W., Xu. M., Zhang. Y. & Clearly. D. J., (2010), 'Macroscopic characteristics for direct injection multiple sprays using dimensionless analysis', Experimental thermal and fluid sciences, Vol. 40, pp:81-92