Effect of Fuel Injection Pressure on Exhaust Emissions of CIDI Engine using Azadirachta Indica Biodiesel and its Diesel Blends

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ABSTRACT

The rapidly increasing global fuel consumption, the diminishing fuel reserves not only raising the import costs of fossil fuel for many countries, but also emitting excessive dangerous emission to environment. These emissions causing concerns on existence of living being on earth and so many researchers started to search for alternative renewable energy resources to replace the petro-diesel fuel to curb the hazardous exhaust gases. In the recent times, biodiesels promising as potential alternative to diesel fuel because there properties are almost nearer to diesel and moreover they are non-toxic, eco-friendly and profusely available at all geographic locations irrespective of regions unlike petroleum wells located mainly in middle-eastern countries. The biodiesel produced from Neem oil has almost similar chemical properties as petro-diesel fuel. The present research paper is aimed to evaluate the effect of fuel injection pressure on exhaust emission characteristics such as CO emission, smoke opacity, and particulate matter of direct injection (DI) diesel engine when fuelled with Azadirachta Indica (neem) oil methyl ester (AIOME). The experimental tests were carried-out in a single cylinder, 4-stroke, water cooled diesel engine fuelled with different blends (B20A, B40A, B60A and B100A) of AIOME biodiesel at various fuel injection pressures ranging from 200-240 bar have revealed that neat AIOME biodiesel has lower CO emission, lower smoke opacity, and lower particulate matter (PM) emissions among all tested blends. It also noted that AIOME percentage in the blend is affecting inversely proportional to exhaust emissions of DI diesel engine. The emissions of the engine are optimal at fuel injection pressure of 210 bar and it can be considered as optimum injection pressure with reference to emission parameters of a single cylinder DI diesel engine.

Keywords - *Biodiesel, Non-edible Oil, Methyl Ester, Azadirachta Indica Oil, Neem Oil Exhaust Emissions, Transesterification.*

I. INTRODUCTION

The energy crisis across the globe due to discrepancy in supply and demand of petroleum fuel, blockage of fossil oil production in some countries such as Venezuela, increase in production cost that speedily raising the fuel prices are not only intimidating the nations' economic and energy security, but also unconvincingly impacting the hazardous environmental pollution. Many researchers have shown much interest to use vegetable oils as alternative to diesel, because vegetable oils can be directly used as fuel without engine modifications [1]. Biodiesels are usually produced from reproducible biological resources such as crude vegetable oils, fats, and tallow. The plants which are source of the raw material could be produced and increased production quickly within one season to meet the increased requirement. In addition to that biodiesels are more environmental friendly than gasoline and petro-diesels and they have almost similar chemical properties [2,3] Many nations have recognized that the commercial production and usage of biodiesel can provide energy security, rural development, trade development, and mitigation of adverse impacts of climate change [4]. At present many countries are using edible oils like soybean, sunflower, rapeseed and palm are used as main biodiesel feed-stocks [5].

The previous research studies ascertains that the most possible way to meet the increasing demand and reduce the dangerous exhaust emissions is by using biodiesels as alternative fuels [6,7]. Huzayyin et al. have conducted experimental studies to evaluate the emission and performance characteristics using Blends of jojoba oil with gas oil and their experimental results shown that slightly reduced engine power, trivial raise in brake specific fuel consumption (BSFC), reduction in NOx and soot emission using blends of jojoba oil with gas oil as compared to gas oil [8]. Deepak Agarwal et al., have investigated the influence of preheated and diesel blends of jatropha curcas oil on the engine characteristics of single cylinder, 4-stroke, DI diesel engine. The experimental results revealed that emission and performance parameters are comparable to petro-diesel fuel, but higher blends have shown slightly lower than diesel. They observed high carbon deposits with all blends and frequent cleaning of filter and combustion chamber was suggested. Finally, they recommended B20 blend as a replacement to petro-diesel fuel, because it has higher thermal efficiency when compared all other blends [9].

Rente et al. investigated the influence of fuel injection pressure on exhaust emissions, soot distribution and flame temperature for a heavy duty, single-cylinder direct injection (DI) diesel engine. They have identified reduced NOx and soot at elevated fuel injection pressures and injection duration was prolonged [10]. Suyawanshi et al. have conducted experimental studies to evaluate the effect of fuel injection timings on emission and performance characteristics of a diesel engine. Their experimental results shown significant improvement in performance and considerable reduction emission characteristics when pongamia oil methyl ester (PME) used as fuel at with retarded fuel injection timings [11]. Basavaraja et al. studied the influence of fuel injection pressure on performance and emissions of a single-cylinder, 4-stroke diesel engine when fueled with pongamia oil (honge oil), pongamia methyl ester and its diesel blends. They noticed improved torque, power and reduced specific fuel consumption and emissions at higher injection pressures. The B20 blend of pongamia methyl ester has shown higher improved performance at 20 MPa injection pressure [12].

II. MATERIALS AND METHODS

The neem oil used for this research work was bought from a local vendor in Chennai, Tamilnadu, India and transesterification was used to reduce the viscosity of the oil and prepared biodiesel. Chemically, biodiesel is a monoalkyl esters of long chain fatty acids derived from vegetable oils or animal fats that meets the ASTM (American Society for Testing Materials) D6751 specifications of DI diesel engines.

(i) Transesterification Process

Biodiesel can be prepared using transesterification, micro-emulsion, pyrolysis, technique or by direct blending with diesel fuel. Transesterification chemical process is one of the best processes to reduce the viscosity of the neem oil and the same process was used in the present research study. The transesterification chemical reaction was presented below in figure 1. These transesterified plant based vegetable oils after chemical reactions with ethyl or methyl alcohol will produce diesel engine friendly fuel.

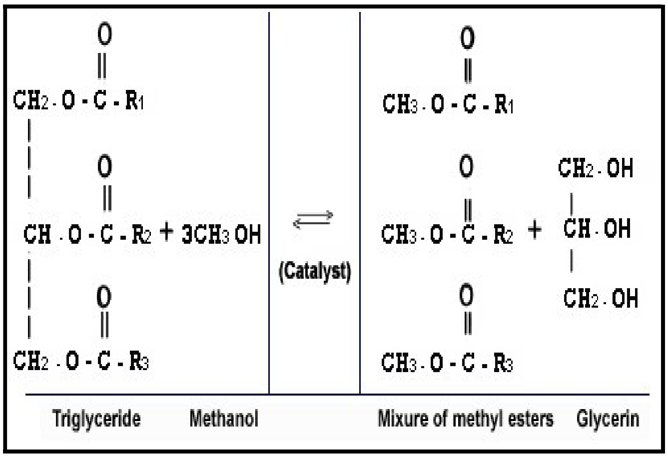

Fig. 1: Transesterification Process

Generally, biodiesels are produced through the reaction of vegetable oils with methanol in the presence of catalyst to yield glycerine and methyl esters. Methanol in the presence of NaOH as a catalyst was used for transesterification of vegetable oil. The parameter involved in the above processing includes the amount of catalyst, reaction temperature, molar ratio of alcohol to vegetable oil, and reaction time. For the present study, Azadirachta Indica (neem) oil that is available in commercial market, Sodium Hydroxide (NaOH), Methanol and distilled water as used as raw material for transesterification process. The fuel properties of diesel and AIOME biodiesel are shown in table 1.

Table 1: Fuel Properties

Fuel Property	ASTM Standard	Diesel	AIOME
Kinematic Viscosity @ 40^{0}C (Cst)	D445	3.52	5.37
Flash Point (^{0}C)	D93	49	165
Density @ 15^{0}C (Kg/m^3)	D1298	840	880
Calorific Value (KJ/Kg)	-	42850	38952
Cetane Number	D613	50	52

(ii) Experimental Test Setup

For the present experimental research study, a single cylinder, 4-stroke, water cooled direct injection (DI) diesel engine was used. The experiment test setup was presented as a schematic diagram in figure 2 and photographic view in figure 3. It consists of a 3.7 KW

(5HP) Kirloskar DI diesel engine, eddy current dynamometer, smoke meter and exhaust gas analyzer. The engine specifications are given in Table 2.

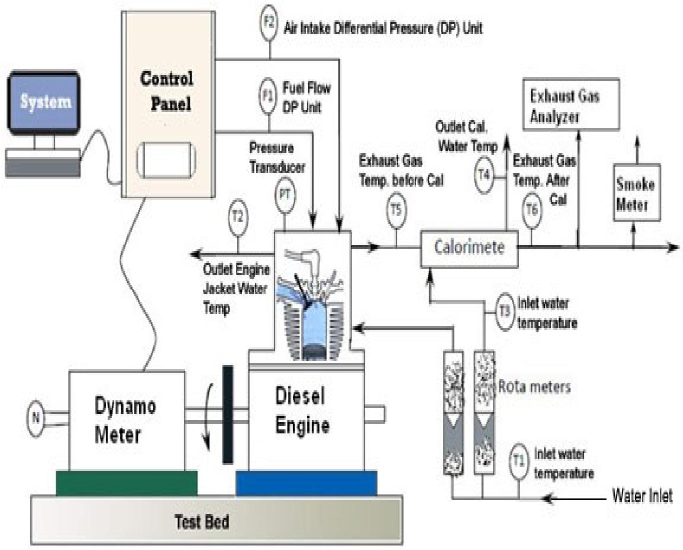

Fig. 2: Schematic Diagram of Experimental Setup

Table 2: Engine Specification

Type	Kirloskar Engine
Details	Single cylinder, Direct injection, 4-Stroke, Water cooled engine
Bore & Stroke	80 × 110 mm
Rated Power	3.7 KW (5 HP)
Speed	1500 rpm
Injection Pressure	200 bar
Dynamometer	Eddy Current

The test engine was initially operated with diesel fuel for only a few minutes and after engine warmup, a series of experimental emission tests were conducted at full load condition with 20% blend of AIOME (B20A) while recording the readings for diffrent injection pressures. Consequently, the same was repeated using different blends of neem oil methyl esters and the readings of each blend for different injection pressures ranging from 200-240 bar were recorded. For each operation, speed of the engine was verified and maintained at rated speed of 1500 rpm. Each experiment was repeated with similar operating condition and each reading was recorded as arithmetic mean of three readings for accuracy. The experimental test data was then analyzed using graphs and are given in the subsequent paragraphs. The carbon monoxide (CO), smoke opacity and particulate matter (PM) were considered as emission characteristics of DI diesel engine for the present research study.

III. RESULTS AND DISCUSSIONS

The exhaust emissions of the single cylinder, DI diesel engine was measured in terms of CO emission, smoke opacity and particulate matter (PM) and presented in below paragraphs.

(i) Emissions of Carbon Monoxide (CO)

Figure 4 shows variation of carbon monoxide emission at various injection pressures. The higher CO emission was observed at 240 bar for all tested blends of AIOME. The emissions of CO reached to minimum at 210 bar of fuel injection pressure. In spite of this, the increase of injection pressure after 230 bar resulted in increase of CO emission as compared to 200 bar of rated fuel injection pressure at full load of the engine.

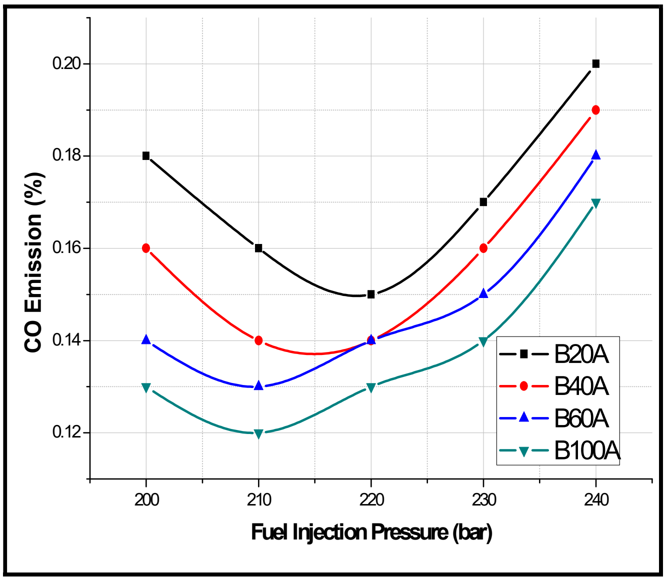

Fig. 4: Variation of CO Emission with different Fuel Injection Pressures for tested blends

The graph is clearly showing that B100A has lower emission values when compare with all other blend percentage of AIOME at all fuel injection pressures. The CO emission is found to increase with the increase in load and decrease with increase in percentage of methyl ester of neem oil (AIOME) in biodiesel blend.

(ii) Smoke Opacity (SO)

The variation of smoke opacity at various injection pressures ranging from 200-240 bar with at constant engine rated speed of 1500 rpm is presented in Figure 5. As shown in graph, an increase in smoke opacity was noticed after 210 bar of fuel injection pressure when compared with rated injection pressure of 200 bar and less value which can be considered as optimum injection pressure was observed at 210 bar. The reduction in smoke opacity revealed with increase of blend percentage of AIOME biodiesel irrespective of fuel injection pressure as presented in figure 5. The smoke opacity of neat biodiesel (B100A) has lowest and B20A blend of AIOME has highest smoke opacity among all tested blends of biodiesel.

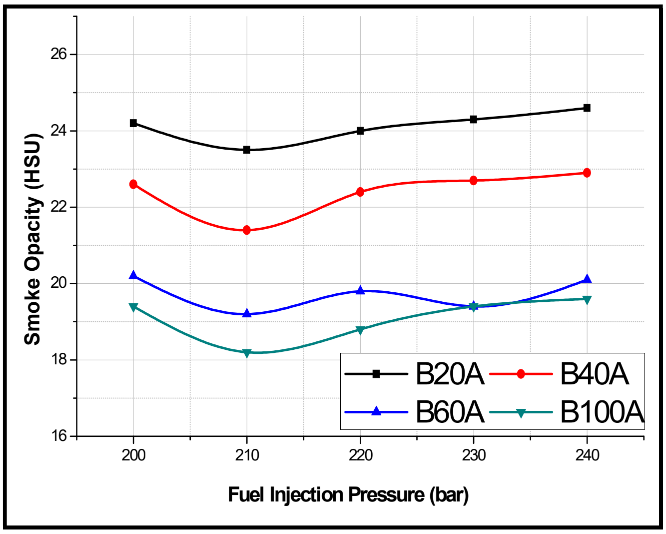

Fig. 5: Variation of Emission of Smoke Opacity with Different Fuel Injection Pressures for tested blends

(iii) Particulate Matter (PM)

The particulate matter (PM) is the most composite of diesel emissions and mostly comprises of both solids, as well as liquid material. Breathing particulate matter has been found to be dangerous for human health, especially in terms of respiratory system problem [13]. The variation of particulate matter (PM) at various fuel injection pressures ranging from 200-240 bar are prsented in figure 6 and the graph is visibly revealing that the particulate matter is lowest at 220 bar for all blend percentages of AIOME at full load condition. The particulate matter (PM) emission increases with increase of injection pressure after 220 bar due to incomplete combustion. The figure 6 is clearly indicating that B100A has lower particulate emission values when compare with all other blend percentage of AIOME at all injection pressures.

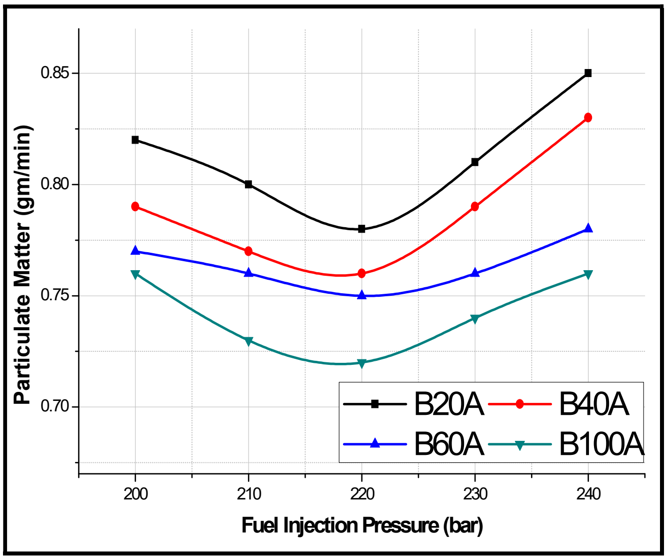

Fig. 6: Variation of Emission of Particulate Matter with Different Fuel Injection Pressures for tested blends

IV. CONCLUSION

The experimental test results of single cylinder, 4-stroke, water cooled diesel engine fuelled with different blends (B20A, B40A, B60A and B100A) of AIOME biodiesel at fuel injection pressures of 200 bar, 210 bar, 220 bar, 230 bar and 240 bar at full load condition revealed the fuel injection pressure is one of the significant engine design parameters that influences on emission characteristics of the DI diesel engine. The results also identified that B100A has lower CO emission, lower smoke opacity, and lower particulate matter (PM) at all injection pressures and optimum emission values were observed at 220 bar. The test results have also revealed the following:

- CO emission from diesel engine was low at 210 bar of fuel injection pressure for all blend percentage of AIOME. The lowest CO emission at 210 bar of injection pressure is 1.9% lower than the CO emission at rated injection pressure.
- The smoke opacity has decreased with the increase of AIOME biodiesel percentage in the blend and the smoke opactiy at 220 bar is about 3% lesser than rated injection pressure of 200 bar
- Particulate matter is lowest at 220 bar for all blend percentages of AIOME at full load condition and is less than 3.9 % when compared with rated fuel injection pressure

The diesel engine with various percentage by volume biodiesel blends of AIOME exhibits very good emission characteristics at fuel injection pressure of 210 bar at full load condition. This can be considered as rated injection pressure when single cylinder, 4–stroke water cooled direct injection compression ignition engine at full load condition when fueled with AIOME biodiesel.

REFERENCES

[1]. Çetinkaya, M., Ulusoy, Y., Tekìn, Y., & Karaosmanoglu, F., 2005, Engine and winter road test performances of used cooking oil originated biodiesel, Energy Conversion and Management, vol. 46, pp.1279-1291.
[2]. Panwar N. L., Shrirame Y. H, Rathore N. S., Jindal S. and. Kur-chania A. K, 2010, Performance Evaluation of a Diesel Engine Fuelled with Me-thyl Ester of Castor Seed Oil, Applied Thermal Engineering, vol. 30, no. 2-3, pp. 245-249.
[3]. Sirivella Vijaya Bhaskar, G. Satish Babu, 2015, Effect of Rice Bran Oil Methyl Ester on Emission Characteristics of CIDI Engine, International Journal of Scientific & Engineering Research, ISSN 2229-5518, vol 6-11, Nov 2015 pp.448-452
[4]. Dufey, Annie, Sonja Vermeulen, and Bill Vorley. Biofuels: Strategic Choices for Commodity Dependent Developing Countries, London, Common Fund for Commodities and International Institute for Environment and Development, 2007
[5]. Ivana B. Bankovi´ c-Ili ´c,Olivera S. Stamenkovi´c,Vlada B. Veljkovi´, 2012, Biodiesel production from non-edible plant oils, Elsevier-Renewable and Sustainable Energy Reviews – 16, 3621– 3647.
[6]. Kawano, D., Ishii, H., Goto, Y., Noda, A. et al., "Effect of Exhaust Gas Recirculation on Exhaust Emissions from Diesel Engines Fuelled with Biodiesel," SAE Technical Paper 2007-24-0128, 2007
[7]. Pryde, E. H, 1982, Vegetable Oil Fuel Standards, Vegetable Oil Fuels, Proceedings of the International Conference on Plant and Vegetable Oils Fuels, St. Joseph, MI, pp.312-328.
[8]. Huzayyin, A.S., Bawady, A.H., Rady, M.A. and Dawood, A. Experimental evaluation of diesel engine performance and emission using blends of jojoba oil and diesel fuel, Energy Conversion and Management, vol. 45, 2004, pp. 2093-2112.
[9]. Deepak Agarwal and Avinash Kumar Agarwal, Performance and emission characteristics of Jatropha oil (preheated and blends) in direct injection compression ignition engine, Applied Thermal Engineering, vol.27, 2007, pp.2314-2323.
[10].Rente, T. and Denbratt, I., Experimental Study of the Combustion Process in a Heavy–Duty DI Diesel Engine for Different Injection Scenarios, SAE Technical Paper 2003-01-1783, 2003, DOI:10.4271/2003-01-1783.
[11].Suryawanshi, J. and Deshpande, N., Effect of Injection Timing Retard on Emissions and Performance of a Pongamia Oil Methyl Ester Fuelled CI Engine, SAE Technical Paper 2005-01-3677, 2005, DOI:10.4271/2005-01-3677.
[12].Basavaraja, T., Reddy, R., and Swamy, V., Effect of Injection Pressure on Emission Performance of Bio-diesel and its Blends, SAE Technical Paper 2005-26-030, 2005, DOI:10.4271/2005-26-030.
[13].N Künzli, R Kaiser, S Medina, M Studnicka, O Chanel, P Filliger, M Herry, F Horak, V Puybonnieux-Texier, P Quénel, J Schneider, R Seethaler, J-C Vergnaud, H Sommer, Public-health impact of outdoor and traffic-related air pollution: a European assessment,The Lancet,vol.356 (9232), 2000, pp. 795-801