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Research Paper

Experimental investigation of emission characteristics of diesel gasoline mixture containing n-butanol

Gopalakrishnan. S [1]*, Srinivaas. A [1]

[1] *Department of Mechanical Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India*
**Corresponding author E-mail: gksomu09@gmail.com*

Abstract

Emissions have become an important parameter, playing an extensive role in the selection of engines. To find out the alternatives for petroleum based fuels owing to their continuous depletion and the increase in emission rates, research works are being carried out continuously. The prime objective of this work is to study the effects butanol additive to the diesel-gasoline mixture fuelled to a CI engine. The operation is carried out by mixing butanol with diesel-4% gasoline mixture at different proportions and the mixtures are used to run a single cylinder APEX 240PE kirloskar make engine at constant speed under a series of load conditions. The performance characteristics of the fuel mixture used is obtained and the concentration of emissions present in the exhaust has been determined using an Emission Analyzer. The mixture can be used as an alternative fuel in diesel engines, thereby producing reduced emission rates.

1. Introduction

Engines are used as a power source in various applications including automobiles, agricultural pumps etc. The number of automobiles in the world is increasing exponentially, but the source of the fossil fuels is being depleted continuously leading to their extinction in an alarming pace [1]. Developing countries like India are importing fuel, directed towards the state of paying a considerable amount to the foreign countries, affecting their national economy. In addition, this increment in the number of automobiles have increased the amount of emissions in the atmosphere leading to various biological effects like acid rains and also causing adverse health effects like skin cancer, lung disorders, eye irritation etc. Various researches are being directed well as to reduce the emissions from the engines. This involves the usage of different biodiesels and chemicals individually in the engines or mixing them with diesel to form blends and use them.

G. Venkat Sundaram and Dr. S. Thirumalini studied the effect of groundnut mixed diesel at 50% in a field marshal diesel engine and concluded that NO_x can be reduced with increase in biodiesel concentration [2]. Boby George and C. Lakshmikanthan analyzed and determined a reduction in the amount of NO_X, HC and CO and a slight increase in the amount of CO_2 by adding 4% of gasoline with diesel [3]. P. Suresh Kumar et al. used the Jatropha biodiesel at different injection pressures and found out that at the pressure range of 160-170 kgf/cm^2 and within the fuel injection angle of 23-25^O, NO_x, HC and CO emissions for the biodiesel was less than that of pure diesel [4]. M. Madhan Kumar and Dr. S. Sunil Kumar Reddy carried out the performance test on the field marshal engine of same power rating with an ethanol diesel blend and diethyl ether as additives at different compositions and declared that at a composition of 10% E (ethanol) and DEE (diethyl ether) each and 80% D (diesel), CO_2 reduced and HC increased and at 40% E + 10% DEE + 50% D, CO was less than the emission rates of a normal blend of 10% E + 90% D [5]. M. Velliangiri and A. S. Krishnan observed a decrease in the concentration of NOx in the exhaust with 95% ethanol and 5% water mixture used as fuel in a single cylinder diesel engine, having combustion chamber coated with zirconia [6]. Minguri Wei et al. used D (diesel)/ gasoline (G)/ B (iso-butanol) blend in a four cylinder diesel engine at five different compositions and revealed that at low loads, 100% D and at high loads, 70% D – 15% G – 15% B were the optimum mixture concentrations for obtaining improved performance and reduced emissions [7]. Ashish Nayyar et al. mixed n-butanol with diesel at different concentrations, used in a Diesel – Kirloskar (TV1) engine and observed that with the blends of 19.82% and 18.84% of butanol with diesel at part loads and full loads respectively, the efficiency increased by 5.54% and NOx reduced by 15.96% than normal diesel [8]. Md Nurun Nabi et al. investigated the usage of neat diesel and diesel butanol blends in a Cummins 6 cylinder in-line engine under 13-mode European stationary cycle and declared that at 6% composition of butanol HC reduced by 36% and at the same time NOx increased by 6.6% than neat diesel [9]. Abhishek Paul et al. used the blend having diesel, diethyl ether and ethanol in a Kirloskar TV1 single cylinder, water cooled diesel engine and concluded that with D80DEE10E10 blend the minimum NOx emissions of 450ppm and 53.14% less CO emissions compared to that of diesel at the full load condition can be achieved [10].

M.S. Gad et al. utilized palm oil biodiesel with diesel in a single cylinder diesel engine of power 5.775 kW and determined that with B20 (20% palm oil with 80% diesel blend), better reduction in HC (39ppm) and CO (0.062%) with a slight increase in NOx (194ppm) can be obtained than pure diesel [11]. Himsar Ambarita tested a small diesel engine with diesel-biogas dual fuel mode and found out that with raw biogas (60% methane concentration) and diesel, maximum brake thermal efficiency of 20% and reduced CO content in exhaust was obtained when compared to enriched biogas (70% methane concentration)- diesel mixture [12].K. Prashant and S. Srihari investigated the characteristics of cotton seed based biodiesel and diesel mixture at different proportions in a GL-400 diesel engine and observed an optimum engine performance with reduced NOx (600ppm), HC (38pppm) and CO

(0.01%) concentration over the given range of increasing load with 20% biodiesel-diesel blend in a PCCI condition [13]. V. Mathan Raj et al. used cotton seed oil and iso-butanol additives to diesel, tested in a high speed, DI diesel engine and declared that diesel with 20% of cotton seed oil and 10% of iso-butanol additives provided comparatively better performance and reduced NOx (290ppm), CO_2 (2.1%) and CO (0.02%) with slight increase in HC content in exhaust without making any changes in the engine system [14]. M. U. Kaisan et al. proposed the idea of using diesel blended with cotton, jatropha and neem oils in a multi-cylinder, stationary diesel engine and observed that the blend having 80 % diesel and 20% cotton produced a lower exhaust temperature, lower NOx and CO_2 emissions with a slight increase in SO_2 content that can be negligible [15]. Haozhong Huang et al. carried out a performance test in a four cylinder CI engine with diesel-butanol blend having Polyoxymethylene Dimethyl Ethers (PODEn) additive and declared that with BD20 (20% butanol) soot emissions reduces (0.001 g/kWh) with slight increase in (0.02-0.05ppm) can be obtained and further reduction can be observed by adding $PODE_{3-4}$ additive [16].

From the above literature survey, it is understood that numerous research studies have been carried out to determine the performance and emission characteristics of different fuel blends. The purpose of this study is to investigate the emission characteristics of four fuel blends having 96%D (Diesel)-4%G (Gasoline) and n-butanol added at proportions of 10%, 15%, and 20% along with normal diesel in a single cylinder, stationary CI engine.

N-Butanol has been taken additive in this test due to the facts that follow [17]:

- Butanol is highly volatile.
- It is able to produce higher energy per unit mass than methanol and ethanol.
- It is less corrosive.
- It has better cetane characteristics compared to others, thereby a more suitable blend for diesel.
- It can easily form a homogeneous mixture with diesel without separation.
- Due to high volatility, the density is also less compared to other additives.

Moreover the production cost and time involved is also similar to the commercialized process of methanol. Hence n-butanol can be considered as the best additive for diesel, comparing to others.

2. Experimental setup

The experimental setup consisted of a single cylinder, APEX 240 PE engine and a computerized control with a constant speed of 1500 rpm as shown in Figure 1. The engine specification is given in Table 1. The engine test was carried out with five different fuel mixtures – 100%D, 96%D + 4% G, 90% (96%D+4%G) + 10%B, 85% (96%D+4%G) + 15%B and 80% (96%D+4%G) + 20%B where D,G and B stand for diesel, gasoline and n-butanol respectively. The chemical properties of diesel, gasoline and n-butanol are given in Table 2.

Fig. 1: Single Cylinder, Stationary, Apex 240 PE Diesel Engine.

Table 1: Engine Specifications [19]

Engine Code	APEX 240 PE
Bore	87.5 mm
Stoke	110 mm
Displacement	1580 cm^3
No. of Cylinders	One
Compression Ratio	17.5
Rated Speed	1500 rpm
Power	10 HP
Maximum Torque	70 Nm
Fuel Consumption	240 g/kWh
Cycle of operation	Four Stroke

The performance parameters were measured using the EngineSoft software and the emissions were measured using an AVL Digas 444 analyzer. The calorific value and density of all the fuel mixtures were determined using bomb calorimeter and hydrometer respectively before using them in the engine (Table 3). The test was carried out with the load conditions varying from no load to full load and the parameters of fuel consumption and the levels of NOx, HC, CO and CO_2 are noted.

Table 2: Properties of Diesel, Gasoline and N-Butanol ([5], [7], [20]-[22])

S. No	Properties	Diesel	Gasoline	n-Butanol
1.	Chemical Formula	$C_{12}H_{23}$	C_8H_{15}	$C_4H_{10}O$
2.	Density (15^{O}C)	840 kg/m^3	744kg/m^3	810 kg/m^3
3.	Boiling Range	150-380 ^{O}C	38-204 ^{O}C	116-118 ^{O}C
4.	Heating Value(MJ/kg)	45	47	34.366
5.	Specific Gravity	0.83	0.739	0.8097
6.	Cetane Rating	46	-	25
7.	Flash Point (^{O}C)	74	52-96	35

Table 3: Properties of Fuel Blends

S. No	Fuels	Calorific Value (kJ/kg)	Density (kg/m^3)
1.	100% D	45080.591	815
2.	96%D+4%G	43826.214	812
3.	90%(96%D+4%G)+10%B	44462.862	809
4.	85%(96%D+4%G)+15%B	44681.578	808
5.	80%(96%D+4%G)+20%B	44801.142	807

3. Results and discussion

The first and foremost thing to be considered during an engine performance test is the fuel consumed by the engine. The specific fuel consumption characteristics of all the fuel blends over the range of varying loads is shown in figure 2.

The fuel consumed by the engine decreases when diesel is mixed with 4% of gasoline because adding gasoline to diesel has lowered fuel density, hence reduces the total fuel density, viscosity and surface tension. Due to this lower surface tension and lower density, fuel droplets injected will become small and the number of small droplets increases than the large ones.

Due to the subsequent ignitions, the mixture burns fully in an effective manner, thereby producing lower fuel consumption [3]. But with the further addition of n-butanol to the mixture, the density of the fuel starts to reduce further and at the same time, due to the difference in the ignition characteristics of all the components, there will be slight reduction in ignition delay. As a result, the fuel consumption slightly increases when n-butanol is added to the diesel-gasoline mixture. Fuel consumption increases with increase in the composition of n-butanol and the variation in specific fuel consumption observed from this experiment ranges between 2-4% with 20% of n-butanol than the normal diesel.

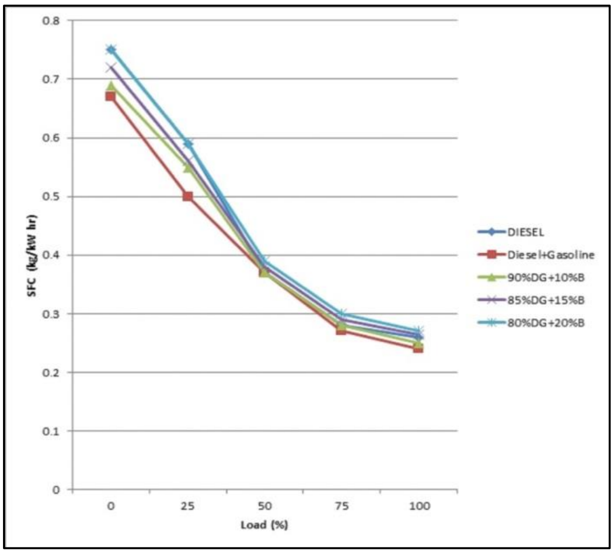

Fig. 2: Specific Fuel Consumption vs. Load.

Blending with n-butanol slightly increases the ignition delay due to its low cetane number and high heat of vaporization than diesel. This in turn gives the fuel enough time to mix in air and tends to reduce cylinder temperature. The reduction in the cylinder temperature results in the lower NOx and HC emissions with butanol added mixture than the normal diesel and diesel gasoline mixture [8]. The emission characteristics of NOx and HC for all the fuel blends are shown in figure 3 and figure 4 respectively.

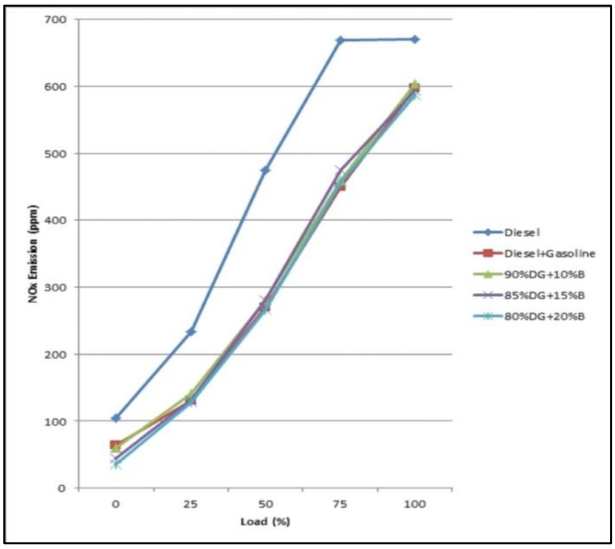

Fig. 3: NOx Emissions vs. Load.

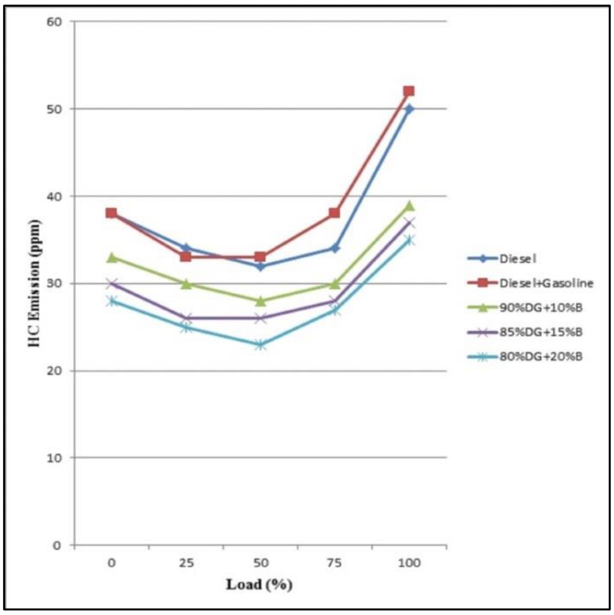

Fig. 4: Hydrocarbon Emissions vs. Load.

Nonetheless adding gasoline and n-butanol has increased slightly the CO_2 concentration in the exhaust at higher loads by 0.8% than the normal diesel. This value is in a close range with the one produced by diesel-gasoline mixture. This slight increment in CO_2 levels can be considered as the positive advantage from the point of emission analysis [3]. The emission levels of CO_2 for all the fuel blends are shown in figure 5.

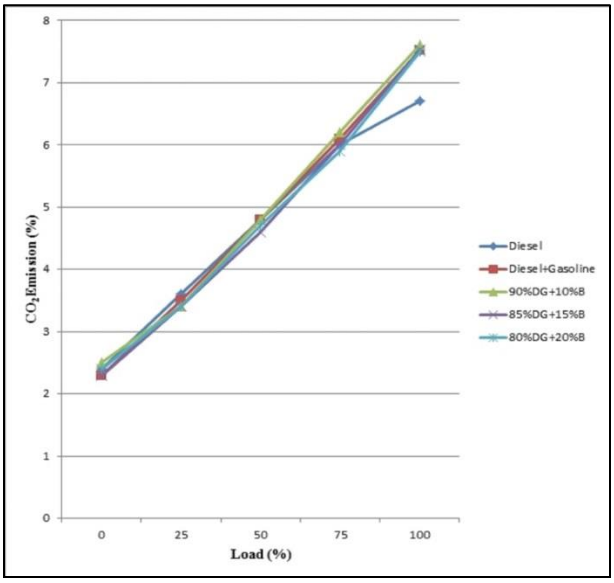

Fig. 5: Carbon Dioxide Emissions vs. Load.

The comparison of the characteristics of the diesel-gasoline and diesel-gasoline with 20% n-butanol mixtures at higher loads are in table 4.

Table 4: Comparison of Parameters

S.No	Parameters	Diesel-Gasoline	80%DG+20%B
1.	Specific Fuel Consumption (kg/kW h)	0.24	0.27
2.	NOx Emission (ppm)	597	587
3.	HC Emission (ppm)	52	35
4.	CO_2 Emission (%)	7.47	7.5

4. Conclusion

The experiment was carried out with the aim of studying the emission characteristics and to find out any reduction in the emission levels produced by the selected fuel blends having different proportions of n-butanol as an additive. Five fuel blends with one being normal diesel was tested in a computer controlled, single cylinder, multi-fuel research engine set-up by varying the load from 0% to 100% with each step having a 25% increment. At the end of the tests, the values were noted; tabulated and characteristic curves were obtained.
It can be determined from the curves that there is a considerable amount of reduction in the emission levels of NOx and HC with the mixture having a concentration of 80%DG and 20%B than the normal diesel and diesel-gasoline mixture, however with a negligible amount of increment in the CO_2 levels.
The notable disadvantage of the mixture is that it has increased fuel consumption than the normal diesel and diesel-gasoline mixture by a maximum variation between 2-5%. This is due to the reduction in the ignition delay than the one occurred with the diesel-gasoline mixture and knocking. One way of rectifying this without making any engine modifications is carrying out the combustion with higher air pressure by incorporating a turbocharger since the test engine does not consisted of turbocharger. With turbocharger, increased air pressure can be achieved and thereby cleaner combustion than the normal condition and better fuel efficiency [18].

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The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ...." Instead, write "F. A. Author thanks ...." Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page.

References

[1] S. V.A. R. Sastry and Ch. V. Ramachandra Murthy, "Prospects of biodiesel for future energy security", *Elixir International Journal*, Vol. 53, pp. 12029-12034, 2012.
[2] G. Venkat Sundaram and Dr. S. Thirumalini, "Experimental Study of Emission and Performance of Single Cylinder Diesel Engine Running On Groundnut Oil Based Biodiesel", *International Journal of Scientific & Engineering Research*, Vol. 5, No. 7, pp. 110-114, July 2014.
[3] Boby George and C Lakshmikanthan, "Experimental Investigation of Diesel Engine Using Gasoline as An Additive", *International Journal of Mechanical Engineering and Robotics Research*, Vol. 3, No. 3, pp. 385-391, July 2014.
[4] P. Suresh Kumar, Ramesh Kumar Donga and P. K. Sahoo, "Experimental Comparitive Study between Performance and Emissions of Jatropha Biodiesel and Diesel under varying Injection Pressures", *International Journal of Engineering Sciences & Emerging Technologies*, Vol. 3, No. 1, pp. 98-112, August 2012.
[5] M.Madhan Kumar and Dr.S.Sunil Kumar Reddy, "Performance Characteristics of Single Cylinder DI Diesel Engine by using Di-Ethyl Ether as an Additive with Diesel Ethanol Blend", *International Journal of Science, Engineering and Technology Research (IJSETR)*, Vol. 4, No. 9, pp. 3272-3275, September 2015.
[6] M. Velliangiri and A. S. Krishnan, "An Experimental Investigation of Performance and Emission in Ethanol Fuelled Direct Injection Internal Combustion Engines with Zirconia Coating", *Journal of Energy Technologies and Policy*, Vol. 2, No. 2, pp. 42-53, 2012.
[7] Minguri Wei et al., "Combustion Performance and Pollutant Emissions analysis using Diesel/Gasoline/Iso-Butanol blends in a diesel engine", *Energy Conversion and Management*, Vol. 149, pp. 381-391, July 2017. https://doi.org/10.1016/j.enconman.2017.07.038.
[8] Ashish Nayyar et al., "Characterization of n-butanol diesel blends an a small size variable compression ratio diesel engine: Modeling and experimental investigation", *Energy Conversion and Management*, Vol. 150, pp. 242-258, August 2017. https://doi.org/10.1016/j.enconman.2017.08.031.
[9] Md Nurun Nabi rt al., "A parametric study on engine performance and emissions with neat diesel and diesel-butanol blends in the 13-Mode European Stationary Cycle", *Energy Conversion and Management*, Vol. 148, pp. 251-259, June 2017. https://doi.org/10.1016/j.enconman.2017.06.001.
[10] Abhishek Paul et al. (2015), "Study of Performance and Emission Characteristics of a single cylinder CI engine using diethyl ether and ethanol blends", *Journal of the Energy Institute*, Vol. 88, No. 1, pp. 1-10, February 2015. https://doi.org/10.1016/j.joei.2014.07.001.
[11] M.S. Gad, R et al., "Performance and emissions characteristics of C.I. engine fueled with palm oil/palm oil methyl ester blended with diesel fuel", *Egyptian Journal of Petroleum*, 2017, to be published. https://doi.org/10.1016/j.ejpe.2017.05.009.
[12] Himsar Ambarita, "Performance and emission characteristics of a small diesel engine run in a dual-fuel (diesel-biogas) mode", *Case Studies in Thermal Engineering*, Vol. 10, No. 1, pp. 179-191, June 2017. https://doi.org/10.1016/j.csite.2017.06.003.
[13] K. Prashanth and S. Srihari, "Emission and Performance Characteristic of a PCCI-DI Engine Fueld with Cotton Seed Oil Bio-Diesel Blends", *ARPN Journal of Engineering and Applied Sciences*, Vol. 11, No. 9, pp. 5965-5970, May 2016.
[14] V. Mathan Raj , L.R. Ganapathy Subramanian and G. Manikandaraja, "Experimental study of effect of isobutanol in performance, combustion and emission characteristics of CI engine fuelled with cotton seed oil blended diesel", *Alexandria Engineering Journal*, 2017, to be published. https://doi.org/10.1016/j.aej.2017.06.007.
[15] M.U. Kaisan et al., "Exhaust emissions of biodiesel binary and multi-blends from Cotton, Jatropha and Neem oil from stationary multi cylinder CI engine", *Transportation Research Part D: Transport and Environment*, Vol. 53, No. 1, pp. 403-414, June 2017. https://doi.org/10.1016/j.trd.2017.04.040.
[16] Haozhong Huang et al., "The potentials for improving combustion performance and emissions in diesel engines by fueling nbutanol/diesel/PODE3-4 blends", *Energy Procedia*, Vol. 105, No. 1, pp. 914 – 920, 2017. https://doi.org/10.1016/j.egypro.2017.03.415.
[17] A. Aziz et al., "The Combustion of n-butanol-diesel blends and its cycle to cycle variability in a modern common rail diesel engine", *ARPN Journal of Engineering and Applied Sciences*, Vol. 11, No. 4, pp. 2297-2301, February 2016.
[18] Murat Karabektas, "The effects of turbocharger on the performance and exhaust emissions of a diesel engine fuelled with biodiesel", *Renewable Energy*, Vol.34, No.4, pp.989-993, April 2009. https://doi.org/10.1016/j.renene.2008.08.010.
[19] APEX INNOVATIONS PVT. LTD., 'Research Engine Test Setup (Computerised) …Code 240PE'. [Online]. Available: http://www.apexinnovations.co.in/pdf/PSP240.pdf. [08- Feb-2013].
[20] World Nuclear Association, 'Heating Values of Various Fuels'. [Online]. Available: http://www.world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx. [Accessed: Sep-2016].
[21] The Engineering Toolbox, 'Liquids and Densities'. [Online]. Available: http://www.engineeringtoolbox.com/liquids-densities-d_743.html.
[22] Chemical Book, '1-Butanol'. [Online]. Available: http://www.chemicalbook.com/ChemicalProductProperty_EN_CB9113046.htm. [Accessed 2017].