Performance and Emission of Diesel Engine Fuelled by Blend of Additives, Biodiesel and Nanoparticles

Nitin Goyal[1] , Monika Khurana[1] , Namita Soni[1] , Monu Gupta[1] , Sumita[1]

1. Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Jaipur.

*Corresponding author email:
E-mail: nitingoyal089@gmail.com

Abstract: This review examines the performance and emission characteristics of diesel engines powered by blends of biodiesel, nanoparticles, and additives. It highlights the potential for reduced emissions (particulate matter, nitrogen oxides, carbon monoxide, and hydrocarbons) and enhanced performance (thermal efficiency, fuel consumption, and power output) using these innovative fuel formulations. The paper explores the impact of additives, biodiesel quality, and nanoparticle type on engine performance and emissions, providing a comprehensive overview of the current state of research in this field. The review concludes by emphasizing the promising prospects and key challenges in adopting these blends to address both environmental concerns and the demand for sustainable diesel engine technology..

Keywords: Energy; Thermal Efficiency, fuel consumption, carbon monoxide, particulate matter and hydrocarbons

1
. Introduction

Due to population growth together with environmental concerns, there is significant demand for carbon-neutral fuels in addition to more stringent legislation governing engine pollutant emissions. This has been attracting new interest in renewable, sustainable and environmentally - friendly energy resources [1,2]. Many techniques have been applied to reduce emissions levels and improve fuel efficiency. The use of additives such as ethanol and butanol in fossil fuels has been investigated extensively and is commercially available [3]. The experimental results of these additives revealed significant reductions in Particulate Matter (PM), hydrocarbon (HC) and carbon monoxide (CO) concentrations [4,5]. Another advantage of using alcohol additives is that they can be derived from renewable biomass resources such as residual agricultural biomass and wastes [6]. These biomass sources are widely available, but it is currently a challenging process to convert them into alcohol biofuels. Among various alcohols, ethanol is the earliest one to be put into the market [7], however some safety and technical concerns remain unresolved [8. It was observed that the addition of the ABE mixture enhanced the evaporation speed of the droplet and thus reduced the lifespan of the droplet. It was found that IBE30 reduced CO and NOx by (4%) and (3.3–18.6%) respectively, compared to gasoline. A number of studies demonstrated some drawbacks when using ethanol as an additive for diesel engines because of the lower heating value and cetane number, and its corrosive behaviour. As ethanol is one of the components in ABE, another alcohol mixture, butanol-acetone (BA), has emerged. BA has a higher fraction of butanol (75%) than ABE and it does not contain ethanol. In a study by Li et al., BA was produced via fermentation of cassava substrate with a ratio of 2.9:1 BA. To our knowledge, BA as an additive to diesel fuel has not yet been investigated. In this article, a BA-diesel fuel blend was investigated in a single-cylinder diesel engine. Both the performance of the engine andexhaust emissions were tested evaluated and compared with diesel fuel.

Tables 1 and 2 illustrate the blend properties of all samples.

Table 1
Diesel fuel, *n*-butanol and acetone specifications [27,30,36].

Fuel properties	Diesel[a] fuel (C4-C12)	*n*-butanol[b] ($C_4H_{10}OH$)	Acetone[b] (C_3H_5OH)
Density @ (20 °C) (g/mL)	0.82–0.86	0.813	0.791
Viscosity@(40 °C) (mm^2/s)	1.3–2.4	2.63	0.35
Lower heating value (MJ/kg)	42.7	33.1	29.6
Auto ignition temp (°C)	230	343	465
Boiling point (°C)	180–360	118	56
Cetane number	50	≅25	

Table 2
Measured properties of test blends.

Blend	Density (g/mL)@ 20 °C	Viscosity (mm^2/s)@ 40 °C	Heating value (MJ/kg)
BA	0.795	1.03	31.43
10BA90D	0.835	2	41.4
20BA80D	0.823	1.8	39.1
30BA70D	0.821	1.77	36.39

2. Results and Discussion

Brake power (BP) and torque (T)

Fig. 1.and Fig 2. present the relationship between engine torque and power and different engine speeds, respectively. The engine was fuelled with different ratios of BA-diesel blends of 10%, 20%, and 30% BA and the results from these tests were compared with diesel fuel. The torque was found to be slightly increased for 10BA-diesel at all engine speeds. However, the torque of 20% and 30% BA-diesel was a slight decrease in all engine speed. The brake power has slightly increased at all engine speed only in the case of the BA ratio of 10% with 5% increment compared with D100.

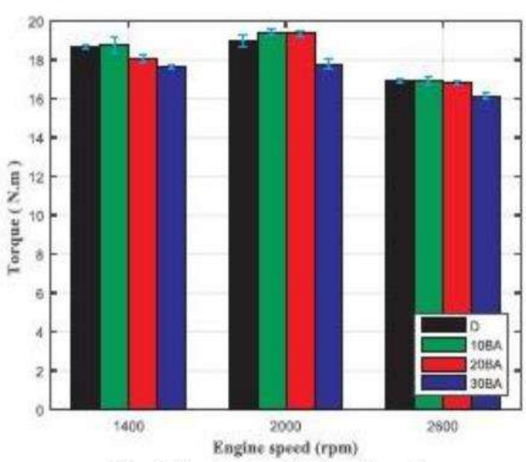

Fig. 1 Torque vs Engine Speed.

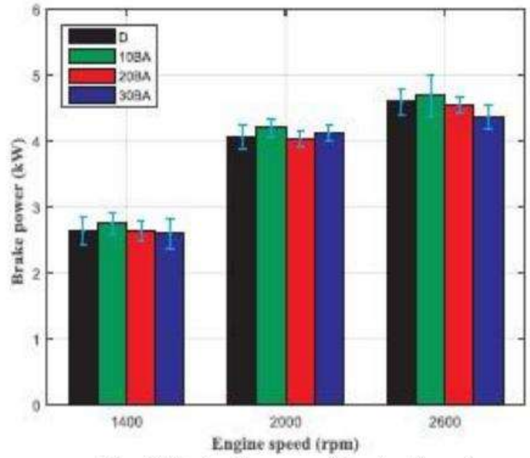

Fig. 2 Brake Power vs Engine Speed.

Brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE)

The effect of BA-diesel fuel blends on BSFC and BTE with the variation of engine speed are illustrated in Fig. 3 and Fig. 4. It was observed that all BA diesel fuel blends increased the BSFC and BTE at all BA blend ratios. The BSFC of the 10BA, 20BA and 30BA diesel fuel increased by, 5.5–6.5%, 1.1–3.45% and 5–14%, respectively, compared with regular diesel at the three-engine speed. With the increased BA addition, the heating value of the BA-diesel decreased by 6.5% at 30BA ratio, which influenced on BSFC significantly. A number of current and previous research has reported similar results of the impact of higher fraction of oxygenated compounds on BSFC of diesel engines. These studies supported the claim that a higher concentration of oxygenated compounds, such as ethanol or butanol and ABE, in fuel mixture reduced the heating value and led to increase the fuel consumption [25]. Therefore, it needs more fuel to match the diesel fuel power.

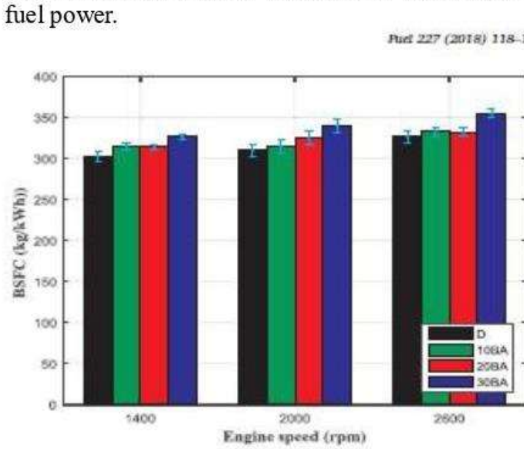

Fig. 3 BSFC vs Engine Speed.

In spite of the fact that BA-diesel fuel blend has increased the BSFC, higher BTE was achieved due to the higher oxygen content in the blend.
As shown in Fig. 4 comparable BTE has been achieved

with 10% BA blend ratio at all engine speeds. However, BTE was increased by 6% and 8% when the BA ratio was 20% and 30% at all engine speeds

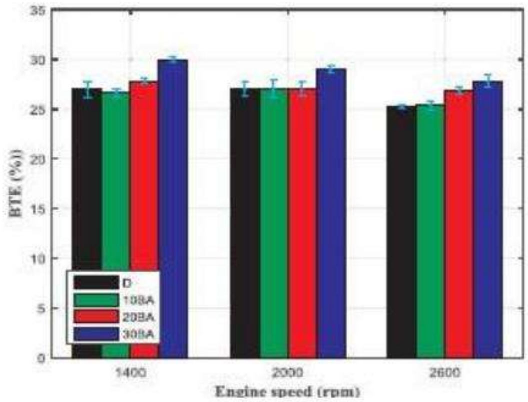

Fig. 4 BTE vs Engine Speed.

Exhaust gas temperature (EGT) and NOx formation

Fig. 5 shows the effect of BA-diesel fuel blend on exhaust gas temperature at various engine speeds. It was observed that exhaust gas temperature of 10BA, 20BA and 30BA-diesel fuel blends reduced by, 2.1–3.5%, 3.4–7.3% and 4.6–15.6%, respectively, compared with regular diesel at the three engine speeds. This reduction may be due to the lower energy content and higher oxygen of the BA-diesel fuel blends. The increasing molecular oxygen content of the fuel blends affects combustion temperature and decreases the energy content of the fuel.

The effect of BA-diesel fuel blends on NOx emission with the variation of engine speed is illustrated in Fig. 6. NOx emission of 10BA, 20BA and 30BA-diesel fuel blends reduced by 2.2–10%, 2.2–7.5% and 2.64–6.6%, respectively, compared with regular diesel at the three engine speeds due to decreased exhaust gas temperature as mentioned above (Fig. 15). Similar trend results were observed in studies of butanol- diesel blend .

1. Conclusions

This experimental study revealed the potential of BA-diesel blends as a promising renewable fuel for CI engine that can be produced by fermentation of waste

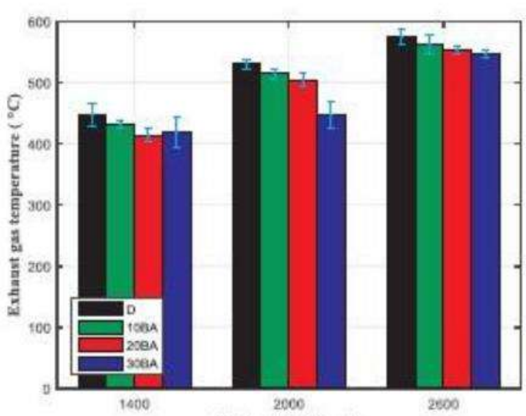

Fig. 5 EGT vs Engine Speed.

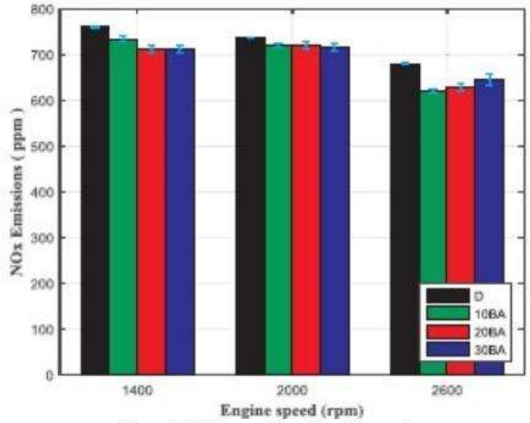

Fig. 6 NOx vs Engine Speed.

The engine performance and emission characteristics between BA-diesel blend and diesel fuels were compared. Some conclusions are as follows: It was found that the combustion phasing was advanced with increasing BA content, which can improve the combustion quality because of the high oxygen content and reduced combustion duration. As a result, 10% BA showed 5% improvement in BP relative to D100, while 20% and 30% BA showed a comparable BP, at all engine speeds. BTE of 10% BA blend was comparable to D100 at all engine speeds; and 6% and 8% higher BTE for BA 20 and 30 at all engine speeds. For the emissions, BA-diesel blend provided better result based on its maximum lower CO (64.5%), NOx (10%) emissions and exhaust gas temperature (15.6%) than those of D100.

4. References

[1] Algayyim SJM, Wandel AP, Yusaf T, Hamawand I. Production and application of ABE as a biofuel. Renew Sustain Energy Rev 2018;82(Part 1):1195–214.

[2] Algayyim SJM, Wandel AP, Yusaf T, Hamawand I, Al-Lwayzy S. Experimental study of spray characteristics, engine performance and emission levels of acetone-butanolethanol mixture-diesel blends in a diesel engine. 11th Asia-Pacific Conference on Combustion. NSW Australia: The University of Sydney; 2017. 10th–14th December.

[3] Algayyim SJM, Wandel AP, Yusaf T. Experimental and numerical investigation of spray characteristics of butanol-diesel blends. 11th Asia-Pacific Conference on Combustion. NSW Australia: The University of Sydney; 2017. 10th–14th December.

[4] Atmanli A, Ileri E, Yuksel B, Yilmaz N. Extensive analyses of diesel–vegetable oil–nbutanol ternary blends in a diesel engine. Appl Energy 2015;145:155–62.

[5] İleri E. Experimental investigation of the effect of diesel–cotton oil–n-butanol ternary blends on phase stability, engine performance and exhaust emission parameters in a diesel engine. Fuel 2013;109:503–11.

[6] Kandasamy M, Hamawand I, Bowtell L, Seneweera S, Chakrabarty S, Yusaf T, et al. Investigation of ethanol

production potential from lignocellulosic material without enzymatic hydrolysis using the ultrasound technique. Energies 2017;10(1):62.
[7] Herzog C, Fryszman A. Perspectives for the utilization of renewable fuels in Latin America. SAE Technical Paper; 1991.
[8] Giakoumis EG, Rakopoulos DC, Rakopoulos CD. Combustion noise radiation during dynamic diesel engine operation including effects of various biofuel blends: a review. Renew Sustain Energy Rev 2016;54:1099–113.
[9] Nasib Q, Sahaa BC, Hectora RE, Hughes SR, Cottaa MA. Butanol production from wheat straw by simultaneous saccharification and fermentation using Clostridium
beijerinckii: Part I—Batch fermentation. Biomass Bioenergy 2008;32:168–75.
[10] Green EM. Fermentative production of butanol—the industrial perspective. Curr Opin Biotechnol 2011;22(3):337–43.
[11] Kujawska A, Kujawski J, Bryjak M, Kujawski W. ABE fermentation products recovery methods—a review. Renew Sustain Energy Rev 2015;48:648–61.
[12] Bellido C, Infante C, Coca M, González-Benito G, Lucas S, García-Cubero MT. Efficient acetone–butanol–ethanol production by Clostridium beijerinckii from sugar beet pulp. Bioresour Technol 2015;190:332–8.
[13] Qureshi N, Blaschek H. ABE production from corn: a recent economic evaluation. J Ind Microbiol Biotechnol 2001;27(5):292–7.
[14] Moradi F, Amiri H, Soleimanian-Zad S, Ehsani MR, Karimi K. Improvement of acetone, butanol and ethanol production from rice straw by acid and alkaline pretreatments. Fuel 2013;112:8–13.
[15] Zhang Y, Hou T, Li B, Liu C, Mu X, Wang H. Acetone-butanol-ethanol production from corn stover pretreated by alkaline twin-screw extrusion pretreatment. Bioprocess Biosyst Technol 2014;37(5):913–21.
[16] Ni Y, Sun Z. Recent progress on industrial fermentative production of acetone-butanol- ethanol by Clostridium acetobutylicum in China. Appl Microbiol Biotechnol 2009;83(3):415–23.
[17] Abd-Alla MH, Zohri AN, El-Enany AW, Ali SM. Acetone-butanol-ethanol production from substandard and surplus dates by Egyptian native Clostridium strains. Anaerobe 2015;32:77–86.
[18] Yang M, Zhang J, Kuittinen S, Vepsäläinen J, Soininen P, Keinänen M, et al. Enhanced sugar production from pretreated barley straw by additive xylanase and surfactants in enzymatic hydrolysis for acetone–butanol–ethanol fermentation. Bioresour Technol 2015;189:131–7.
[19] Sunwoo IY, Hau NT, Ra CH, Jeong G-T, Kim S-K. Acetone-Butanol-Ethanol production from waste seaweed collected from Gwangalli Beach, Busan, Korea, based on pH-controlled and sequential fermentation using two strains. Appl Biochem Biotechnol 2018.
[20] Van Geem KM, Cuoci A, Frassoldati A, Pyl SP, Marin GB, Ranzi E. An experimental and kinetic modeling study of pyrolysis and combustion of acetone–butanol–ethanol (ABE) mixtures. Combust Sci Technol 2012;184(7–8):942–55.
[21] Wu H, Nithyanandan K, Zhang J, Lin Y, Lee TH, Lee C, et al. Impacts of acetone– butanol–ethanol (ABE) ratio on spray and combustion characteristics of ABE–diesel blends. Appl Energy 2015;149:367–78.
[22] Wu H, Nithyanandan K, Zhou N, Lee TH, Lee C-FF, Zhang C. Impacts of acetone on the spray combustion of Acetone–Butanol–Ethanol (ABE)-Diesel blends under low ambient temperature. Fuel 2015;142:109–16.
[23] Wu H, Nithyanandan K, Lee TH, Lee C-FF, Zhang C. Spray and combustion characteristics of neat acetone-butanol-ethanol, n-butanol, and diesel in a constant volume chamber. Energy Fuels 2014;28(10):6380–91.
[24] Zhou N, Huo M, Wu H, Nithyanandan K, Lee C-FF, Wang Q. Low temperature spray combustion of acetone–butanol–ethanol (ABE) and diesel blends. Appl Energy 2014;117:104–15.
[25] Lin Y, Wu H, Nithyanandan K, Lee TH, Chia-fon FL, Zhang C. Investigation of high percentage acetone-butanol-ethanol (ABE) blended with diesel in a constant volume chamber. ASME 2014 Internal Combustion Engine Division Fall Technical Conference. American Society of Mechanical Engine