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EFFECT ON PERFORMANCE AND EMISSIONS OF ALUMINA NANO ADDITIVES WITH RICE BRAN BIODIESEL ON COMPRESSION IGNITION ENGINES: AN EXPERIMENTAL STUDY

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Abstract

The abatement and recession of fossil fuel in the current situation and pollution after its use is a major concern to the people. Biodiesel emerged as an alternative of fossil fuel in the recent past. The properties of biodiesel are better than the diesel fuel and the properties of nanoparticles have fascinated the researchers to use them as additives with the fuel in CI engines due to their better thermo physical and thermo chemical properties. In this comparative experimental study, B10, B20 and B30 biodiesel of rice-bran oil blended with 30PPm Al2O3 nanoparticles and neat diesel as a base fuel were used. Rice-bran BD is prepared after using the transesterification process and ultrasonication process is mixed with Al2O3 nanoparticles. The four-stroke diesel engine acted at 0 kW, 1.5 kW, 2.5 kW, 3.5 kW loads and at a Constant speed of 1500 RPM was used in this study. The optimum results for engine performance and exhaust emission were found for the blended fuels. The blend resulted in maximum improvement in BSFC and BTE by40% and 6.79% respectively at the maximum load (3.5 kW) and 1.5 kW for RB20Al30 and B30 respectively and maximum diminishment of exhaust emissions of CO2 by 7.4% and 2.94% at 0 kW and 1.5 kW loads for B20 and B10. The reduction of NOX by 20.23% (for RB30Al30) and 15.54% (for RB10Al30) at 0 kW and 1.5 kW respectively was achieved. The UBHC got reduced by18.51% (for RB30Al30) and 15.38% (for D100Al30) at 0 kW and 2.5 kW loads.

Keywords: Nanoparticles, Biodiesel, Performance, Exhaust Emissions, CI engine.

1.Introduction

With increasing pollution from the transportation sector, the world now a days is facing many issues related to emissions. Due to increasing pollution, issues related to human health, natural disasters and global warming are also arising. Moreover, with increasing fuel costs, people's incomes as well as savings are also getting affected. Therefore, to enhance the performance of engines and reduction in emissions related to it has become the need of the hour. It has been found that once biodiesel gets blended with nanoparticles giving out nano fuel, can serve as a solution to this problem. In this experimental study 30 PPM of aluminum oxide (Al2O3) blended with rice bran biodiesel is used with diesel for increasing the combustion properties

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such as maximum cylinder pressure, rate of EGT as well as performance of engine such as BTE and BSFC and to reduces the emissions such as oxides of nitrogen (NOX), carbon mono-oxide, carbon dioxide (CO2) and hydrocarbon (HC) as well as noise pollution (dBa) without any modification into engines. Many of the researchers experimented with different nanoparticles, some of which are metal oxide nanoparticles like aluminum oxide (Al2O3), copper oxide (CuO), iron oxide (Fe2O3), zinc oxide (NO), silicon oxide (SiO2), titanium oxide (TiO2) etc. and some are non-metal oxides like Graphene oxide (GO) and carbon nano tubes (CNT) along with Graphene oxide). They found different results on engine variables.

Adding nanoparticles as an additive to biodiesel has attracted many researchers in recent years to improve the efficiency and emissions characteristics of fuels that reduce emission while enhancing efficiency [1–4]. Due to nanoparticles, the thermo physical properties of fuel increase. Increasing the concentration of nanoparticles in fuel increases thermo physical properties such as higher surface to volume ratio and thermal conductivity. A variety of oxygen effects on biofuels have recently been investigated to improve IC engine efficiency and emission [5,6]. Moreover, using nanoparticles as fuel additives acts as a highly reactive agent in the combustion process and increases flash point, fire point and thermal conductivity and at the same time it reduces the viscosity [5 -7].

Many researchers have experimented to investigate the effects of nanoparticles with biodiesel in CI engines. Elwardany et. al. [8] investigated the results for ferrocene nanoparticles with diesel and biodiesel at 300, 250, 200, 150, 75 and 50 PPM concentrations. Better results of the ferrocene blend were found between 300 and 250 PPM concentrations. It resulted in8% and 3%increment in cylinder pressure and BTE as well as NOX got reduced after mixing nano additive in diesel and biodiesel. However, it enhances CO2 content in the exhaust emissions. Seesy et. al. [9] experimented and made numerical observations with Al2O3 nanoparticles and jojoba biodiesel at concentrations of 10 to 50 PPM. The results showed a rise in peak cylinder pressure, rate of pressure rise and rate of heat release. It observed 12% reduction into BSFC and 15% enhancement to BTE. After analyzing exhaust emission, it found 70%, 80%, 35% and 60% decrement in NOX, CO, smoke opacity and UBHC respectively as compared to that of Jojoba 20 mg/l biodiesel. Better explanations of these results are defined byAl. Widyan M. et. al. [10]and Shehata et. al. [11].

Properties of Rice Bran biodiesel was also studied by a few researchers. In an experimental study of Rice Bran biodiesel with single cylinder four stroke engine at 500 RPM and two modes have been analyzed by Acharya et. al. [12]. Firstly, it reported BSFC decreases well as decrease in exhaust emissions such as UBHC and CO at preheated stage at 1200C [13]. Aalam and Sarvanan [14]and two more researchers carried out the results of Al2O3 nanoparticles with emulsified Mahua oil BD and diesel. They found increments in cylinder pressure, peak pressure and heat release rates and also found diminishment in BSFC. The performance was improved and emissions such as NOX, CO, and UHBC decreased after adding alumina nanoparticles [15, 16]. In another studies alumina (Al2O3) with 5% and 10% WCO biodiesel were studied by Hosseini et. al. [17]. The results showed the increase in torque, BTE, EGT and power by 5.36%, 10.63%, 5.80% and 5.36% respectively.

An experimental result carried out using with aluminum oxide (Al2O3) nanoparticles and diesel butanol mixture fuel blend (B20) by Fayad et al. [18] examined the better stability of fuel and found 13%, 4.7% and 6%improvement in heat release rate, BTE and cylinder pressure respectively. The BSFC, HC, CO and NOX were reduced by7.3%, 37.46%, 42.71% and 12.37% respectively.

2.Materials and Methods

Rice bran oil is a non-edible oil which is produced from the wastage (husk) produced during the processing of paddy to rice. India is the second largest production hub of rice. According to the information from Government of India, production of rice oil was1031 lakh tones in the year 2016-2017 and there was a significant rise in its per hectare production from 2019 to 2020. The rice bran biodiesel is produced by Transesterification process from the reaction aided by heterogeneous catalyst, homogeneous catalyst and many times by both. The alkalis and acids are found in the homogeneous catalyst [19]. The production of rice bran oil is by means of the following reactions.

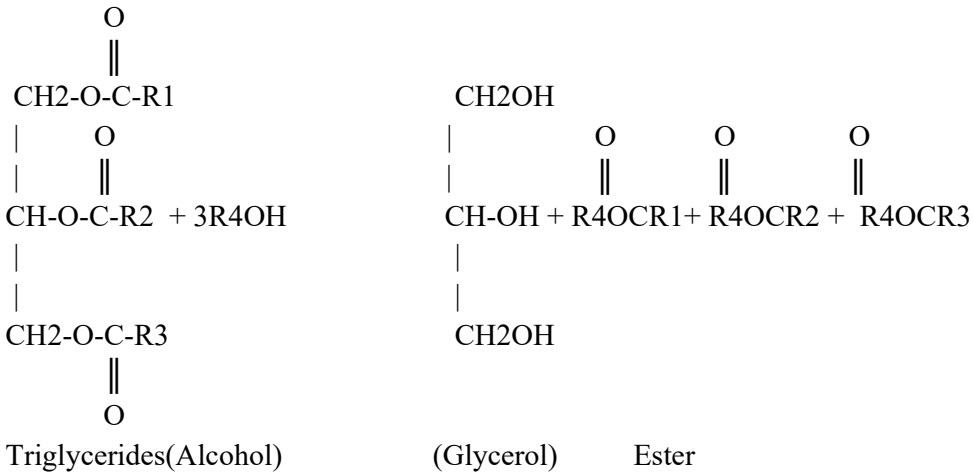
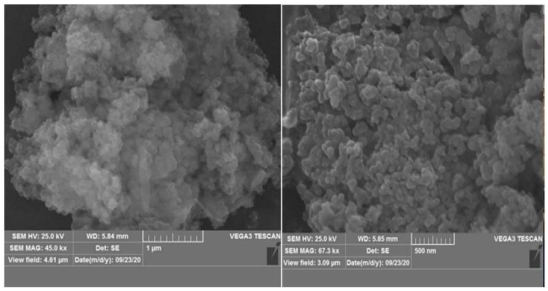


Figure 1 Chemical Reaction in the process of Transesterification method [19].

Nanoparticles used for blending in the fuel are nano sized (50nm). It causes the nanoparticles to mix easily into the fuel and it does not get stuck up during the injection process. Nanoparticles (aluminum oxide) are shown in the SEM images in Figure 2.



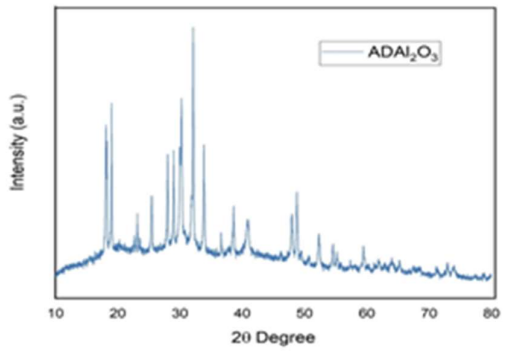


Figure 2 SEM images and Graph for intensity of Al2O3.

The fuel is prepared by Ultrasonication process. Three types of biodiesels (B10, B20and B30) were used for the experiment. The B10 biodiesel is prepared after mixing of 10% rice bran biodiesel, B20 biodiesel after mixing of 20% rice bran biodiesel and B30 is prepared by 30% rice bran biodiesel respectively with 70% diesel. To prepare
the fuel blend diesel and biodiesel is mixed with the use of magnetic stirrer for up to 1.5 hours and after that 30 PPM of aluminum oxide (Al2O3) nanoparticles are added in to fuel by the help of ultrasonication process. After that the fuel blend is kept on for 24 hours, it is then used into a diesel engine. The properties of Diesel (base fuel), biodiesel and nanoparticles are shown in Table 1. Nanoparticles for this experiment have been purchased from Ad Nano Technologies Pvt. Ltd. Karnataka, India.

Figure 3 magnetic stirrer process for fuel preparation.

Table 1 Properties of materials

Item	Value
Molecular Formula	Al_2O_3
Particle Size	50 nm
Molecular Weight	101.96 g/mol

Bulk Density	0.5 g/cm^3
Melting Point	2055^{0}C
Purity	99.9%

Table 2 Properties of fuel.

Properties/ fuel	D100 (Neat)	B10	B20	B30	RB10Al30	RB20Al30	RB30Al30	Standard
Density, Kg/m^3, 15^{0}C	837	831	835	852	834	852	886	ASTM D-1298
Heating Value (MJ/Kg)	44.0	45.43	45.90	44.05	45.8	46.12	46.52	ASTM D240
Kinematic Viscosity, 40^{0}C	3.8	3.31	3.79	4.9	3.21	3.13	3.05	ASTM 7042
Flash point (^{0}C)	74	185	188	76	82	84	85	ASTM D-93

3. Experiment Setup

The water cooled four-stroke single cylinder diesel engine is used for this experimental study as shown in Error! Reference source not found. which acts at a constant speed of 1500 RPM and with 15.1 compression ratio. The experimental study is done after applying different loads such as 0kW, 1.5kW, 2.5kW and 3.5kW. For the measurement of fuel properties, various types of instruments according to ASTM standards are used [20]. After preparing the fuel, it is required to measure the viscosity, calorific value/Heating value, density and flash point by the use of viscometer, bomb calorimeter (as shown in Figure 5),
hydrometer and Pensky-Martens closed cup tester respectively. The specifications of the engine are as shown inTable 3. The aqua gas analyzer is used for the measurement of emissions (Figure 4). After the test of fuel properties, it was found that the properties of biodiesel (B10, B20, B30) and Biodiesel with nanoparticles blended fuel (RB10Al30, RB20Al30, RB30Al30) is better than that of neat diesel fuel (D100). After measuring the properties, it was found that the density and heating value of blended fuel has enhanced and the viscosity of fuel is reduced after the mixing of biodiesel and Al2O3 nanoparticles in to the base fuel (neat diesel).

Figure 4 Experimental setup for this research

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Table 3 Diesel Engine Specification

Item	**Value**
Engine manufacturer	Bharat
Cooling Method	Water-Cooled
Number of cylinders	1
Speed	1500 RPM
Injection Method	Direct Injection
Bore × Stroke	(87.5 × 110) mm.
Compression ratio	16.5:1
Engine capacity	1 HP
Rated power	7.5 kW

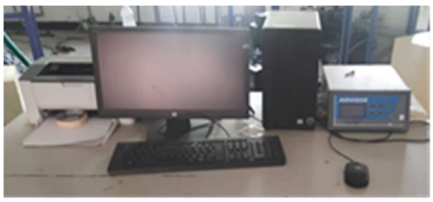

Figure 4 Setup for Emission measurement.

Figure 5 Bomb Calorimeter.

4.Results and Discussion

The outcome attained are mentioned through graphs and their respective parameters.

Analysis on Performance of CI Engine-

Analysis for BSFC-

This factor measures performance of a diesel engine based on its specific fuel consumption. It is determined when 1 litre of fuel gets consumed in 1hour time period when the engine performs at different loads. After mixing the nanoparticles, the BSFC improves at all loads, but when nanoparticles are mixed with the neat diesel, it gives the lowest consumption results for the D100Al30 fuel at a high load (3.5 kW). The maximum enhancement of 27.96%, 30.9%, and 40%was found for RB20Al30, RB30Al30 and RB20Al30 at 1.5kW, 2.5kW and 3.5kW respectively. This happens due to the higher oxygen content available to biodiesel due to mixing of Al2O3 nanoparticles which gives the better atomization to the fuel facilitating its proper burning and thus increasing the temperature in the combustion chamber. Due to this phenomenon heat release rates also improves.

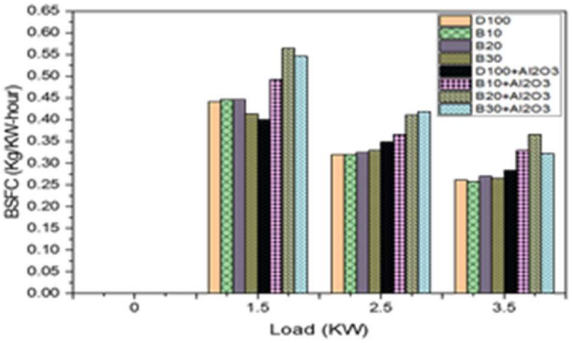

Figure 6 Graph for BSFC versus loads.

Brake Thermal efficiency-

The BTE of and engine is determined by the ratio of loads or brake power to the fuel energy supplied. It can describe the maximum load multiplication of heat energy flow for combustion and how much engine works mechanically. The efficient result was found due to better combustion property of blended fuel. When the nanoparticles are mixed with biodiesel it enhances the combustion property and causes the BTE increase. The outcome attained for B30 fuel is 6.79% increase when compared to neat diesel (D100) at 1.5 kW load. But as the load and concentration of biodiesel is increased, reduction of BTE is observed.

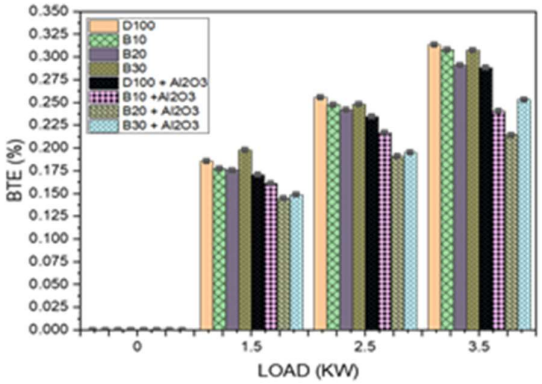

Figure 7 Graph for BTE versus Loads.

Analysis on Exhaust Emissions-The main aim of this research is to attain reduction in major harmful exhaust emissions from the engine.

CO Emission-

The CO emission from the RBME with Al2O3 varies at all loads. The use of nano additive blended fuel led to CO content in the exhaust. The CO content gets increased after the use of all biodiesel blended fuel with Al2O3 nanoparticles in comparison to neat diesel. This is because due to more flash point temperature which enhances the delay of combustion of fuel and due to its oxygen content, the fuel burns slightly faster giving rise to increased temperature of combustion chamber. In this experimental study CO emission is equal for B10, B20, B30, D100Al30, RB10Al30 fuel at 1.5 kW and for B10 at 2.5 kW load to the neat Diesel (D100).

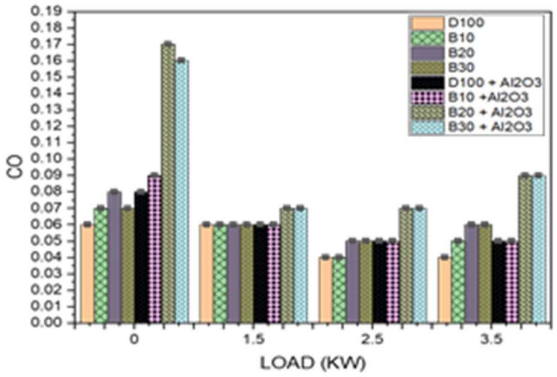

Figure 8 Graph for CO emission versus Loads.

CO_2 Emissions-

The CO_2 emission gets increased due to better atomization of fuel which provides excessive amount of oxygen in the fuel. Due to this, CO gets converted into CO_2 [21]. The percentage of CO_2 content for nano fuel depends upon its CO content. The reduction of CO content shows the increment in CO_2 content [13]. Finally, the CO_2contentdepends upon the Equivalence ratio of air- fuel mixture. To achieve reduction in CO_2, it is important that mixture should be rich one. This experimental study found the improvement in CO2content as compared to that of neat diesel. The maximum decrease of 7.4% and 2.94% for B20 and B10 at 0 kW and 1.5 kW load respectively were found in the experiment. The value of CO2 emission remains equal for B10 at 2.5 kW load.

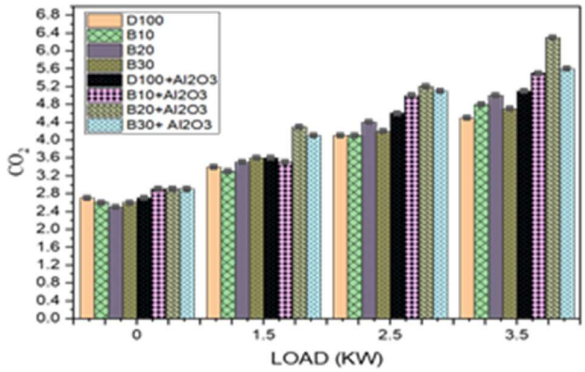

Figure 9 Graph for CO_2 versus Loads.

NOX Emissions-NOX is responsible for global warming as it affects the ozone layer directly. In this experimental study, NOx reduces maximum by 20.23% from the exhaust. This is because of excess amount of oxygen the favourable temperature conditions available in the combustion chamber. By the effect of thermal conductivity of Al2O3 nanoparticles, the temperature gets reduced and it results in the diminishment in NOX content at 0, 1.5, 2.5- and 3.5-kW load respectively with values by 20.23%, 15.54%, 11.30%, 9.89% forRB30Al30, RB10Al30, RB30 and RB30 respectively in comparison with neat diesel (D100).

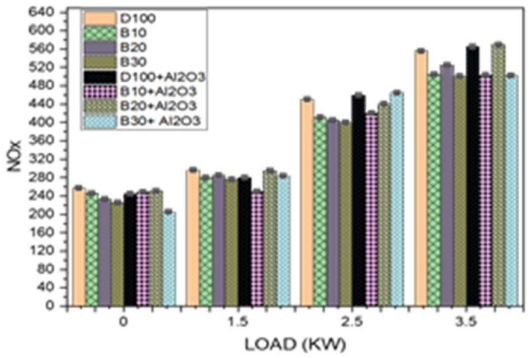

Figure 10 Graph for NO_X versus loads.

UBHC Emissions-For the purpose of pollution Control from the exhaust emission it is important to control the hydrocarbon content from the exhaust. In this experiment the HC was measured at various loads and concentration of biodiesel with 30PPm alumina nanoparticles and found the better results. The unburnt hydrocarbons are caused due to incomplete combustion. If once proper combustion takes place into chamber the hydrocarbon content gets reduced [22]. In this experimental study, due to more oxygen content and better thermo physical properties of nanoparticles, proper combustion takes place at the 0, 1.5, 2.5- and 3.5-KW loads at constant speed. Maximum diminishment in the HC content of18.51% for RB20Al30, RB30Al30 without applying any load was attained. At 1.5 kW load are applied, reduction by 7.69% for D100Al30, RB10Al30 and at 2.5 kW load reduction by 15.38% for D100Al30 was achieved. At full load (3.5 kW) HC content increased for all concentration of fuels.

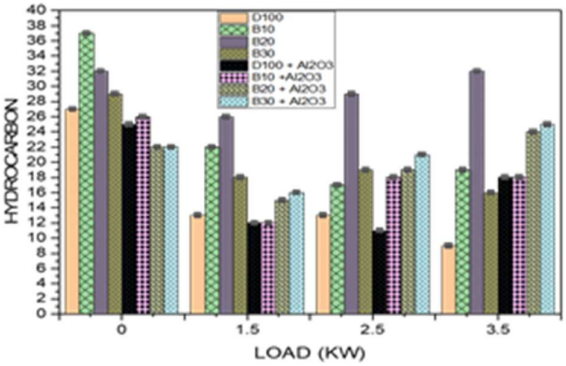

Figure 11 Graph for HC versus Loads.

Conclusion-After using alumina nanoparticles with rice bran biodiesel, very effecting results on performance and emissions were attained. Due to the easy availability of rice bran, properties of aluminium oxide nanoparticles, the sulphur content from the exhaust emission was negligible. The series of activities performed during the experiment and the conclusions so achieved are summarized as follows:

- The four-stroke water cooled single cylinder diesel engine was used at various load (0 kW, 1.5 kW, 2.5 kW and 3.5 kW) and constant speed of 1500 RPM.
- The effect of Al2O3 nanoparticles and rice bran biodiesel blended fuel on engine performance such as increment in BSFC by 40% for RB20Al30 at 3.5 kW load and enhancement in BTE by 6.79% for RB30 at 1.5 kW load in comparison to neat diesel (D100) was observed.
- This experimental study showed better results for exhaust emissions. The emission of CO was found to be equal to that of neat diesel for all concentration of fuel at 1.5 kW except RB20Al30 and RB30Al30. It was also equal for RB10 at 2.5 kW load.
- The maximum reduction of 7.4% in emission of CO2was found for B20 fuel at 0 kW load and 2.94% for B10 at 1.5 kW load, but at 2.5 kW load, the CO2 content for RB10was equal to that which is applicable for neat diesel.
- NOX content decreased by 20.23 %, 15.54%, 11.30% and 9.89% for RB30Al30, RB10Al30, RB30 and RB30 at 0 kW, 1.5 kW, 2.5 kW and 3.5 kW respectively.
- The experimental study showed the maximum diminishment of UBHC emission by 18.51% for RB20Al30 and RB30Al30at 0 kW and 15.38 % for D100Al30 at 2.5 kW load.
- The overall summery of this experimental study is that the use of alumina nanoparticles with rice bran BD is very effective to enhance the performance and control of pollution. The addition of the Al2O3 nano additives in the fuel affected the combustion properties. Further research needs to be done with some modifications with injection timings with the CI engines. It can give better results for CO and HC emissions.
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- Conflicts of Interest
The authors have no conflicts of interest to declare.

- **References**

[1] A.I. EL-Seesy, Z. He, H. Hassan, D. Balasubramanian, Improvement of combustion and emission characteristics of a diesel engine working with diesel/jojoba oil blends and butanol additive, Fuel.279(2020)118433. https://doi.org/10.1016/J.FUEL.2020.118433.

[2] A.I. EL-Seesy, T. Xuan, Z. He, H. Hassan, Enhancement the combustion aspects of a CI engine working with Jatropha biodiesel/decanol/propanol ternary combinations, Energy

Conversion and Management. 226 (2020) 113524. https://doi.org/10.1016/J.ENCONMAN.2020.113524
[3] A.I. EL-Seesy, H. Hassan, Investigation of the effect of adding graphene oxide, graphene nanoplatelet, and multiwalled carbon nanotube additives with n-butanol-Jatropha methyl ester on a diesel engine performance, Renewable Energy.132(2019)558–574. https://doi.org/10.1016/J.RENENE.2018.08.026.
[4] A. Prabu, Nanoparticles as additive in biodiesel on the working characteristics of a DI diesel engine, Ain Shams Engineering Journal. 9(2018)2343–2349. https://doi.org/10.1016/J.ASEJ.2017.04.004.
[5] M.F. Al-Dawody, M.S. Edam, Experimental and numerical investigation of adding castor methyl ester and alumina nanoparticles on performance and emissions of a diesel engine, Fuel.307(2022). https://doi.org/10.1016/j.fuel.2021.121784.
[6] M.E.M. Soudagar, N.N. Nik-Ghazali, M. Abul Kalam, I.A. Badruddin, N.R. Banapurmath, N. Akram, The effect of nano-additives in diesel-biodiesel fuel blends: A comprehensive review on stability, engine performance and emission characteristics, Energy Conversion and Management. 178(2018)146–177. https://doi.org/10.1016/J.ENCONMAN.2018.10.019.
[7] V. Saxena, N. Kumar, V.K. Saxena, A comprehensive review on combustion and stability aspects of metal nanoparticles and its additive effect on diesel and biodiesel fuelled C.I. engine, Renewable and Sustainable Energy Reviews.70(2017)563–588. https://doi.org/10.1016/j.rser.2016.11.067.
[8] A.E. Elwardany, M.N. Marei, Y. Eldrainy, R.M. Ali, M. Ismail, M.M. El-kassaby, Improving performance and emissions characteristics of compression ignition engine: Effect of ferrocene nanoparticles to diesel-biodiesel blend, Fuel.270(2020). https://doi.org/10.1016/j.fuel.2020.117574.
[9] A.I. El-Seesy, A.M.A. Attia, H.M. El-Batsh, The effect of Aluminium oxide nanoparticles addition with Jojoba methyl ester-diesel fuel blend on a diesel engine performance, combustion and emission characteristics, Fuel.224(2018)147–166. https://doi.org/10.1016/j.fuel.2018.03.076.
[10] M.I. Al-Widyan, M.A. Al-Muhtaseb, Experimental investigation of jojoba as a renewable energy source, Energy Conversion and Management.51(2010)1702–1707. https://doi.org/10.1016/J.ENCONMAN.2009.11.043.
[11] M.S. Shehata, S.M.A. Razek, Experimental investigation of diesel engine performance and emission characteristics using jojoba/diesel blend and sunflower oil, Fuel.90(2011)886–897. https://doi.org/10.1016/J.FUEL.2010.09.011.
[12] S.K. Acharya, R.K. Swain, M.K. Mohanty, The Use of Rice Bran Oil as a Fuel for a Small Horse-power Diesel Engine, Http://Dx.Doi.Org/10.1080/15567030902967827.33(2010)80–88. https://doi.org/10.1080/15567030902967827.
[13] A.T. Hoang, M. Tabatabaei, M. Aghbashlo, A.P. Carlucci, A.I. Ölçer, A.T. Le, A. Ghassemi, Rice bran oil-based biodiesel as a promising renewable fuel alternative to Petro diesel: A review, Renewable and Sustainable EnergyReviews.135(2021). https://doi.org/10.1016/j.rser.2020.110204.

[14] C.S. Aalam, C.G. Saravanan, Effects of nano metal oxide blended Mahua biodiesel on CRDI diesel engine, Ain Shams Engineering Journal.8(2017)689–696. https://doi.org/10.1016/J.ASEJ.2015.09.013.
[15] J. Sadhik Basha, R.B. Anand, Role of nanoadditive blended biodiesel emulsion fuel on the working characteristics of a diesel engine, Journal of Renewable and Sustainable Energy.3(2011)023106. https://doi.org/10.1063/1.3575169.
[16] J.S. Basha, R.B. Anand, An Experimental Study in a CI Engine Using Nanoadditive Blended Water–Diesel Emulsion Fuel, Http://Dx.Doi.Org/10.1080/15435075.2011.557844.8(2011)332–348. https://doi.org/10.1080/15435075.2011.557844.
[17] S.H. Hosseini, A. Taghizadeh-Alisaraei, B. Ghobadian, A. Abbaszadeh-Mayvan, Effect of added alumina as nano-catalyst to diesel-biodiesel blends on performance and emission characteristics of CI engine, Energy. 124 (2017) 543–552. https://doi.org/10.1016/j.energy.2017.02.109.
[18] M.A. Fayad, H.A. Dhahad, Effects of adding aluminium oxide nanoparticles to butanol-diesel blends on performance, particulate matter, and emission characteristics of diesel engine, Fuel. 286(2021). https://doi.org/10.1016/j.fuel.2020.119363.
[19] S. Sinha, A.K. Agarwal, S. Garg, Biodiesel development from rice bran oil: Transesterification process optimization and fuel characterization, Energy Conversion and Management.49(2008)1248–1257. https://doi.org/10.1016/j.enconman.2007.08.010.
[20] K. Ebrahimi, D. Gordon, P. Canteenwalla, C.R. Koch, Evaluation of ASTM D6424 standard for knock analysis using unleaded fuel candidates on a six-cylinder aircraft engine, ttps://Doi.Org/10.1177/14680874211008703. (2021). https://doi.org/10.1177/14680874211008703.
[21] S. Vellaiyan, K.S. Amirthagadeswaran, Zinc oxide incorporated water-in-diesel emulsion fuel: Formulation, particle size measurement, and emission characteristics assessment, Http://Dx.Doi.Org/10.1080/10916466.2015.1122621.34(2016)114–122. https://doi.org/10.1080/10916466.2015.1122621.
[22] Pj. Prakash, Gr. Reddy, Bs. Rao, Performance of DI Diesel Engine with Rice Bran Biodiesel and Al 2 0 3 Nano Additive, International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE). 2 (2017) 2456–1290.