A COMPREHENSIVE REVIEW ON THE EFFECT OF NANO-ADDITIVES IN DIESEL-BIODIESEL FUEL BLENDS

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ABSTRACT

The paper discusses the potential of biodiesel as an alternative liquid fuel. Biodiesel offers benefits such as extended engine life, clean burning, and reduced greenhouse gas emissions due to the trees used for feedstock absorbing carbon. It also helps reduce dependence on fossil fuels and supports the economy. However, biodiesel faces challenges like high viscosity, poor cold flow properties, increased nitric oxide emissions, and low oxidation stability compared to conventional diesel. One promising solution is the addition of nanoparticles, which enhance the fuel's thermochemical properties. The paper explores studies on nano-sized particles in diesel-biodiesel fuel emulsions, focusing on their impact on engine performance, emissions, and longevity. It also delves into the effects of different nanoparticle sizes and concentrations on diesel engine behaviour. Additionally, the paper covers the preparation of nanofluid, various characterization methods, and techniques for enhancing the stability of biodiesel.

1. INTRODUCTION

The Sustainable Development Goals (SDGs) are closely linked to energy conversion systems, as energy plays a crucial role in various sectors like transportation, homes, industries, agriculture, and commerce worldwide. Fossil fuels, due to their reliability, high conversion efficiency, accessibility, and versatility, have become a dominant energy source. However, since they are finite and consumption rates are increasing, a shortage is inevitable. Burning fossil fuels leads to the release of harmful pollutants, including carbon monoxide (CO), hydrocarbons (HC), particulate matter, and nitrogen oxides (NOx), contributing to issues like acid rain, greenhouse gases, smog, and climate change. To mitigate emissions from diesel engines, various strategies can be employed, such as engine design modifications, improved combustion processes, exhaust treatment, and the use of specialized additives. Oxygenated fuels like biodiesel are a promising alternative to conventional diesel.

2. LITERATURE REVIEW

A. Devaraj et al. [1] studied about the effect of nano particles on engines performance and emission parameters and engine life. They also studied about the effect of different size and dosage of nano particles on diesel engine behaviour.

S. O. Bitire and T.-C. Jen [2] had conducted an experimental study on a central composite design (CCD) embedded in RSM (response surface methodology) to optimize a biodiesel blend containing different concentrations (50 and 100 ppm) of a green synthesized nanoparticle. The obtained results showed that the B20TNP50 blend gave the best performance and emission characteristics of 325.862 g/kWh, 28.021%, 5.008 MJ/kW, 0.021 g/kWh, 327.725 g/kWh, 0.0013 g/kWh, and 1.760 g/kWh for brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), brake specific energy consumption, (BSEC), hydrocarbon (HC), carbon dioxide (CO2), carbon monoxide (CO), and oxides of nitrogen (NO_x) respectively.

H. Hanbey and H. Sevinc [3] experimentally analysed the influences of grape seed oil-propanol fuel mixture, which can be an alternative to diesel fuel, on diesel engine. The results indicated that BSFC, Co, smoke and HC diminished but NO_x, BTE, EGT, vibration and noise increased in the preheated and propanol added test fuels. Preheating process for grape seed oil ensured a convenient fuel flow and decreased the oil viscosity and propanol addition contributed to the enrichment of the fuel in terms of oxygen.

Ümit Ağbulut [4] experimentally investigated the thermodynamical and economical role of nanoparticle size on a CI engine performance. Collectively, average energy efficiencies of test fuels are 6.65% bigger than exergy efficiencies. In the conclusion, this paper declares that the particle size of nanomaterials is a very effective physical property on the IC engine performance, and the small particle sizes of the same type nanoparticles should be preferred in terms of better energy, exergy, thermoeconomic, exergoeconomic, and sustainability results.

Vijaya Kumar et al. [5] conducted an experimental study with an intention to enhance the engine characteristics of Palmyra oil methyl ester (POME) blended diesel by the approach of varying the compression ratio, different EGR rates along the amalgamation of Nano additives in the fuel. From the experimental results it was observed that brake thermal efficiency was enhanced by 2.72% and BSFC was lowered by 7.8% and reduction in exhaust emissions like carbon monoxide, unburnt hydrocarbons and smoke opacity by 17.64%, 13.8% and 3.5% respectively were found at CR20:1 when related to CR18:1, but NOx emissions were found to be increased. While the added 6% and 12% of EGR to POME20-CR20 results showed a reduction in the NO_x emission compared to diesel. Though the 12% EGR has shown a greater reduction in NO_x its performance has greatly deteriorated than the 6% EGR. However, the result of amalgamating the fuel with alumina and ceria nanoparticles has given encouraging BSFC results, compared to diesel fuel POME20 at CR20 and 6% of EGR added with 100 ppm of Al_2O_3 and CeO_2 nanoparticles was less than 15.15% and 6.06%.

M. Gülüm [6] experimentally investigated the combined effects of engine speed, compression ratio and biodiesel content on both performance and exhaust emissions as well as fuel cost. At each compression ratio, the biodiesel-diesel fuel blends produce lower CO, HC and smoke but higher $CO_2$and NOx emissions. As compression ratio is increased, brake effective power, brake effective efficiency, NO_X and CO_2 increase while brake specific fuel consumption, brake specific energy consumption, CO, HC and smoke decrease for all test fuels. Moreover, the biodiesel-diesel fuel blends increase fuel cost in the range of 51.2862 %-213.8935 % on average, compared to DF.

M. Nagappan et al. [7] experimentally studied about application of additives in biodiesel to enhance its behaviour. The current study concluded that use of additives in biodiesel can be a vital solution to improve combustion, performance, and emission characteristics of engine.

A. T. Hoang et al. [8] experimentally studied critical role of metal nanoparticles in the support of diesel engine behaviours using biodiesel and diesel. As a result, the use of biodiesel with the presence of metal nanoparticles is considered as the potential strategy for promoting spay and atomization, enhancing the combustion process, increasing brake thermal efficiency (BTE), reducing toxic emissions (including carbon monoxide (CO), unburnt hydrocarbon (HC), and smoke), and improving tribology characteristics. However, some drawbacks are also indicated, such as increased NOx emission and brake-specific fuel consumption.

Ghanbari et al. [9] experimentally investigated the effect of alumina nanoparticles concentration in diesel–biodiesel blended fuels and engine speed on the performance and emission characteristics of a six cylinder, four-stroke diesel engine. The maximum values of brake power and torque were obtained as 42.82 kW and 402.8 Nm for nanoparticle concentration of 160 ppm and engine speed of 1000 rpm, respectively. Experimental results showed that alumina nanoparticle is a good addition for diesel–biodiesel blends to improve the performance and decrease the emissions of diesel engine.

V. W. Khond et al. [10] conducted an experimentally study in which ignition probability of fuel and performance, emission of a twin cylinder, water cooled, Kirloskar diesel engine fuelled with D75NB25 biodiesel blend with dosing of 200 ppm nano iron oxide, silicon dioxide and zinc oxide fuel additives were tested and compared with pure D75NB25. It was evident from result that NO_x was increased however; unburned hydrocarbon and carbon monoxide emission was reduced in all nano fuel additive blended fuel than D75NB25 blend. Smoke opacity was significantly reduced with addition of nano particles. Also, addition of nano fuel additives significantly enhances the ignition probability of D75NB25 biodiesel blend.

Kiran et al. 2021 [11] evaluated the performance parameters of a diesel engine fuelled with standard diesel and chrysopogon zizanioides nano particle mixed biodiesel blends. Engine emission tests for diesel fuel with chrysopogon zizanioides nanoparticles were performed. From the experimental results, it was observed with the addition of nano particles decreases emissions of hydrocarbons and carbon monoxide, carbon dioxide, nitrogen oxide, smoke and increases oxygen and proved that the fuel prepared with nano additives could be a replacement for the standard diesel.

A. Murugesan et al. [12] investigates the performance of direct injection compression ignition engine fuelled with waste cooking oil biodiesel blend (B20) with and without nano additive dispersion. It was noted from the research work that the presence of highly reactive surface promoted the chemical reactivity which resulted in better combustion. The brake thermal efficiency and specific fuel consumption of nanoparticles dispersed biodiesel blend improved by 1.6% and 8%. The study of combustion parameters revealed that nano dispersed fuels advanced the start angle of combustion, allows more fuel to react with oxygen and enhances rapid evaporation.

D. Pélerin et al. [13] compared the combustion and emission characteristics between different neat OME fuels and a reference paraffinic diesel fuel (PDF) varying several operating parameters of a single cylinder heavy duty research engine. It is shown that ethylene propylene diene rubber (EPDM) is an alternative sealing material for an engine operation only with long-chained OME.

H. Venu and P. Appavu [14] emphasized the characteristics of combustion, performance, and emissions of Polanga Biodiesel (PBD) fuelled single-cylinder diesel engine with Al_2O_3 nano-additives added at a concentration of 25 ppm and 50 ppm. Experimentation results revealed that the addition of the nanoparticles in PBD improved the combustion and emission characteristics of base fuel due to higher surface area to volume ratio of nano-additives. Moreover, Al_2O_3 nanoparticles addition enhanced the brake thermal efficiency (BTE) and lowered the brake specific fuel consumption (BSFC) by 6.58% and 7.38% respectively.

H. A. Dhahad and M. T. Chaichan [15] evaluated the performance and pollution of a diesel engine not equipped with exhaust gas post-treatment equipment adding aluminium oxide and zinc oxide nanoparticles to conventional Iraqi diesel. The results indicated that adding 100 ppm of nano-alumina gave the best results: It reduced specific fuel consumption by 8% and increased the brake thermal efficiency by 6%. The 100-ppm nano-alumina decreased CO, HC, TSP, SO_2, and H_2S by 17%, 17%, 26%, 19% and 19%, respectively. The NO_x increased by 10%. The study results indicate a significant improvement in engine performance and a clear reduction in most emissions. In the future, the method proposed by the study will play an important role in improving unmodified diesel engine outputs using Iraqi diesel with nanoparticles addition.

H. A. Dhahad et al. [16] experimentally investigated that adding nanomaterials to diesel fuel can improve the quality of fuel combustion and reduce pollutant emissions depending on the additive. Results showed that adding the nanomaterials significantly affected the ignition and increased the maximum pressure inside the cylinder. The addition of nano- TiO_2 and nano- Al_2O_3 also increased the brake thermal efficiency of conventional diesel from 18.9% to 24.25% and 20.45%, respectively. The maximum pressure inside the cylinder under total load conditions reached 62 bar and increased to 63.2 and 60.4 bar after the addition of 25 ppm of nano- Al_2O_3 and nano-TiO_2, respectively.

S. Janakiraman et al. [17] studied the comparative behaviour of various nano additives namely; Cerium oxide (CeO_2), Zirconium oxide (ZrO_2) and Titanium oxide (TiO_2) with B20 blend (20% Garcinia gummi-gutta biodiesel + 80% diesel) in Kirloskar make, TAF-1 single cylinder engine. Results revealed that the optimized B20 (Garcinia)+ TiO_2 (25 ppm) fuel blend possess greater impact and it had nearer performance, reduction in CO, UBHC and smoke emissions, lowered combustion with diesel fuel. Also, this fuel blend had a steep increment in NO_x and CO_2 emission with diesel fuel at peak load.

S.S. Hoseini et al. [18] experimentally investigated the effects of graphene oxide (GO) nano-particles on performance and emissions of a diesel engine fuelled with Oenothera Lamarckian biodiesel. Biodiesel was used in the blend of B20. Results showed that by using GO, power and EGT significantly increase. Furthermore, by using GO nano-particles, significant reductions in CO (∼5%–22%) and UHCs (∼17%–26%) were observed. However, under similar conditions, a slight increase in CO_2 (∼7%–11%) and NO_x (∼4%–9%) emissions observed.

S. Vellaiyan and C. A. Partheeban [19] experimentally investigated the effect of water emulsion and ZnO nanoparticle on the emissions pattern of a diesel engine running with SB. The experimental results reveal that SB20W emulsion fuel promotes a drop of 41.4% and 28.3% in NOx and smoke emissions at BP of 2.56 kW compared to SB, respectively. SB10W emulsion fuel promotes an improvement of 40% and 33.3% in HC and CO emissions compared to SB at 2.56 kW BP, respectively. An inclusion of ZnO nanoparticle in SB20W emulsion fuel significantly reduces the NO_x, HC, CO and smoke emissions irrespective of load conditions, and an increase in the mass fraction of nanoparticle further reduces the emissions level.

Akram et al. [20] conducted an experimental study to evaluate reduction in CO, NO_x and UBHC of synthetic biodiesel based on waste cooking oil at various concentrations of CeO_2 nanoparticles and Ce0.5Co0.5 nano-composite oxide at full engine load. The comparative analysis indicated the significant reductions in gaseous emissions from burning of pure diesel, biodiesel and additives enriched biodiesel blends. The Ce0.5Co0.5 nano-

composite oxide performance was comparatively better than CeO_2 regarding the reduction of exhaust emissions resulted from the combustion of various biodiesel blends.

Gharehghani & Pourrahmani [21] experimentally studied 36 different cases of the input parameters (different values of biodiesel, water, and nano-particles). Results indicated that the best performance occurs when the amount of cerium oxide nano-particles is 80 ppm, while the shares of biodiesel and water are 6 percent.

M. Soudagar et al. [22] experimentally investigated the effects of graphene oxide nanoparticles on performance and emissions of a CI engine fuelled with dairy scum oil biodiesel. The results were notable enhancements in the performance and emissions characteristics, the brake thermal efficiency improved by 11.56%, a reduction in brake specific fuel consumption by 8.34%, unburnt hydrocarbon by 21.68%, smoke by 24.88%, carbon monoxide by 38.662% for the nano fuel blend DSOME2040 and oxides of nitrogen emission by 5.62% for fuel DSOME(B20). Similarly, the addition of graphene nanoparticles in DSOME fuel blends resulted in significant reduction in the combustion duration, ignition delay period, improvement in the peak pressure and heat release rate at maximum load condition.

P. Dinesha, Shiva Kumar & Marc A. Rosen [23] experimentally investigated the effects of water emulsion and diethyl ether additive on the combustion performance and emissions of a compression ignition engine using biodiesel blends on a four stroke, single cylinder diesel engine. The results show that, compared to biodiesel operation, the brake thermal efficiency of the emulsified fuel increases slightly with the composition of diethyl ether, and the maximum brake thermal efficiency is obtained at 2% diethyl ether.

Venu, Subramani & Raju [24] conducted an experimental study on EGR of B30 (30% palm biodiesel-70%diesel) blended with 25 ppm TiO_2 nanoparticles (PBN). Experimental test results obtained for PBN-EGR were outstanding than the conventional PB-EGR system since there is a noticeable drop in BSFC, HC and CO emissions with increase in EGT (exhaust gas temperature) than PBN.

I. Örs [25] conducted an experimental study in which waste cooking oil biodiesel was mixed with titanium dioxide (TiO_2), a metal-based nano particle, and n-butanol (C4H9OH) along with euro diesel to examine their effects on diesel engines. The results of exhaust emission showed a decrease in CO, HC and smoke opacity emissions, whereas increased CO_2 and NO emission, except the use of n-butanol reduced the values of NO emission, in comparison to euro diesel and without TiO_2 additive. The results show that biodiesel produced from waste cooking oil, n-butanol and TiO_2 additive can be used in diesel engines at certain proportion and that the additive materials improve the combustion characteristics, engine performance and exhaust gas emission.

A. Praveen et al. [26] experimentally investigated the performance and emission characteristics of a single-cylinder diesel engine using Calophyllum Inophyllum biodiesel blends with TiO2 nano additives and exhaust gas recirculation (EGR). NOx emissions were reduced by the EGR technique and increased by the addition of TiO2 nanoparticles to the biodiesel blend compared to B20 fuel. The biodiesel blend Calophyllum Inophyllum (B20) with the addition of TiO2 nanoparticles and EGR technology was found to be characterized by improved engine performance and lower greenhouse gas emissions compared to other fuels.

V. K. Nema and A. Singh [27] studied the effect of Nano fuel additive Aluminium Oxide (Al_2O_3) on the emission reduction using of soybean methyl ester and rapeseed methyl ester dual blended biodiesel in a single cylinder, water cooled, direct injection diesel engine. It was observed that NO_x emission was higher at dual biodiesel operation compared with diesel operation and it was conquered by introduction of Nano-fuel additive in dual fuel additives which resulted in 10% cutback in NO_x emission.

3. CONCLUSION

A comprehensive review on nano-additives preparation to their application in diesel and biodiesel fuels has been presented in preceding sections. The inclusion of nanoparticles in liquid fuel can offer many advantages, such as the enhancement in performance and reduction in exhaust emission. The following section summarizes the findings from the exhaustive literature survey and a proposition is presented for the study of nanoparticles as an additive for diesel and biodiesel fuel.

- The addition of metal-based (Mn, Ni, Mg, Co) additives and few oxygenated additives to the biodiesel blend decreases the viscosity, density and flash point, though, the oxygen content of the blend is increased. Although, few antioxidant additives increased the cetane number and the flash point.

- A lower BSFC is preferred for the higher engine efficiency but, most of the studies reported an increase in BSFC with the inclusion of biodiesel due to the lower heating competence and lower calorific value, hence the amount of the biodiesel emulsion fuel required to reduce BSFC and increasing the efficiency will be higher.

- The stability of the nanoparticles plays a vital role in the study of performance enhancement and emission reduction of diesel-biodiesel fuel blend with NPs additives.

- It is essential to conduct investigational studies on the selection of an effective surfactant to avoid the agglomeration and precipitation of nanoparticles.

- The nanofluids should be improved and optimized with respect to the properties such as stability, particle size distribution, material, temperature, and shape.

- The metallic and CNTs nano-additives were found favourable with respect to their effects on emission reduction and engine performance enhancement.

- TiO_2 additives were more effective in enhancing the engine power. Addition of metallic NPs resulted in reduced ignition delay period, enhanced the calorific value and oxidation rates leading to a complete and cleaner combustion.

REFERENCES

[1] A. Devraj, M. Nagappan, D. Yogaraj, O. prakash, Y. Anupam Rao and A. Sharma, "Influence of nano-additives on engine behaviour using diesel-biodiesel blend," *Materials Today,* pp. 2266-2270, 2023.

[2] S. O. Bitire and T.-C. Jen, "An optimization study on a biosynthesized nano-particle and its effect on the performance-emission characteristics of a diesel engine fueled with parsley biodiesel blend,," *Energy Reports,,* vol. 9, pp. 2185-2200, 2023.

[3] H. Hanbey and H. Sevinc, "Investigation of exhaust emissions and performance of a diesel engine fueled with preheated raw grape seed oil/propanol blends,," *Chemical Engineering and Processing - Process Intensification,,* vol. 188, p. 109378, 2023.

[4] Ümit Ağbulut, "Understanding the role of nanoparticle size on energy, exergy, thermoeconomic, exergoeconomic, and sustainability analyses of an IC engine: A thermodynamic approach,," *Fuel Processing Technology,* vol. 225, p. 107060, 2022.

[5] P. V. Kumar, B. Ashok, M. S. kumar, R. Vignesh, J. P. Bhasker and A. N. Kumar, "Evaluation of performance, emissions and combustion attributes of CI engine using palmyra biodiesel blend with distinct compression ratios, EGR rates and nano-particles,," *Fuel,,* vol. 321, p. 124092, 2022.

[6] M. Gülüm, "Effects of compression ratio, blending ratio and engine speed on fuel cost, performance and exhaust emissions of a diesel engine fueled with bio-derived alternative fuels,," *Sustainable Energy Technologies and Assessments,,* vol. 53 Part A, p. 102464, 2022.

[7] M. Nagappan, . A. Devaraj, , J. M. Babu, N. V. Saxena, Om Prakash, P. Kumar and A. Sharma, "Impact of additives on Combustion, performance and exhaust emission of biodiesel fueled direct injection diesel engine,," *Materials Today: Proceedings,,* vol. 62, pp. 2326-2331, 2022.

[8] A. T. Hoang, M. X. Le, S. Nižetić, Z. Huang, Ü. Ağbulut, I. Veza, Z. Said, A. T. Le, V. D. Tran and X. P. Nguyen, "Understanding behaviors of compression ignition engine running on metal nanoparticle additives-included fuels: A control comparison between biodiesel and diesel fuel,," *Fuel,,* vol. 326, p. 124981, 2022.

[9] M. Ghanbari, L. Mozafari-Vanani, M. Dehghani-Soufi and A. Jahanbakhshi, "Effect of alumina nanoparticles as additive with diesel–biodiesel blends on performance and emission characteristic of a six-

cylinder diesel engine using response surface methodology (RSM),," *Energy Conversion and Management: X,,* vol. 11, p. 100091, 2021.

[10] V. W. Khond, K. Rambhad and V. Shahadani,, "New diesel-neem biodiesel blend (D75NB25) containing nano iron oxide, silicon dioxide and zinc oxide for diesel engine: An experimental investigation,," *Materials Today: Proceedings,* vol. 47, no. 11, 2021.

[11] S. S. Kiran, S. Madhu, C. Bibin, M. M. Woldegiorgis and P. Kumran, "Effects of chrysopogon zizanioides nano additive with palm biodiesel on engine performance and exhaust emissions,," *Materials Today: Proceedings,,* vol. 45, no. 7, pp. 6951-6957,, 2021,.

[12] A. Murugesan, A. Avinash, E. J. Gunasekaran and A. Murugaganesan, "Multivariate analysis of nano additives on biodiesel fuelled engine characteristics,," *Fuel,,* vol. 275, p. 117922, 2020.

[13] D. Pélerin, M. Härtl, E. Jacob and G. Wachtmeister, "Potentials to simplify the engine system using the alternative diesel fuels oxymethylene ether OME1 and OME3−6 on a heavy-duty engine,," *Fuel,,* vol. 259, p. 116231, 2020.

[14] H. Venu and P. Appavu, "Al2O3 nano additives blended Polanga biodiesel as a potential alternative fuel for existing unmodified DI diesel engine,," *Fuel,,* vol. 279, p. 118518, 2020.

[15] H. A. Dhahad and M. T. Chaichan, "The impact of adding nano-Al2O3 and nano-ZnO to Iraqi diesel fuel in terms of compression ignition engines' performance and emitted pollutants,," *Thermal Science and Engineering Progress,* vol. 18, p. 100535, 2020.

[16] H. A. Dhahad, S. A. Ali and M. T. Chaichan, "Combustion analysis and performance characteristics of compression ignition engines with diesel fuel supplemented with nano-TiO2 and nano-Al2O3,," *Case Studies in Thermal Engineering,,* vol. 20, p. 100651, 2020.

[17] S. Janakiraman, T. Lakshmanan, V. Chandran and L. Subramani, "Comparative behavior of various nano additives in a DIESEL engine powered by novel Garcinia gummi-gutta biodiesel,," *Journal of Cleaner Production,,* vol. 245, p. 118940, 2020.

[18] S. S. Hoseini, G. Najafi, B. Ghobadian and M. Ebadi, "Performance and emission characteristics of a CI engine using graphene oxide (GO) nano-particles additives in biodiesel-diesel blends,," *Renewable Energy,,* vol. 145, pp. 458-465, 2020.

[19] S. Vellaiyan and C. A. Partheeban, "Combined effect of water emulsion and ZnO nanoparticle on emissions pattern of soybean biodiesel fuelled diesel engine,," *Renewable Energy,,* vol. 149, pp. 1157-1166, 2020.

[20] S. Akram, M. W. Mumtaz, M. Danish, H. Mukhtar, A. Irfan, S. A. Raza, Z. Wang and M. Arshad, "Impact of cerium oxide and cerium composite oxide as nano additives on the gaseous exhaust emission profile of waste cooking oil based biodiesel at full engine load conditions," *Renewable Energy,* vol. 143, pp. 898-905, 2019.

[21] A. Gharehghani and . H. Pourrahmani, "Performance evaluation of diesel engines (PEDE) for a diesel-biodiesel fueled CI engine using nano-particles additive," *Energy Conversion and Management,* vol. 198, p. 111921, 2019.

[22] M. S. Manzoore Elahi., N.-N. Nik-Ghazali, M. A. Kalam, I. A. Badruddin, N. R. Banapurmath, T. Y. Khan, M. N. Bashir, N. Akram, R. Farade and A. Afzal, "The effects of graphene oxide nanoparticle additive stably dispersed in dairy scum oil biodiesel-diesel fuel blend on CI engine: performance, emission and combustion characteristics,," *Fuel,* vol. 257, p. 116015, 2019.

[23] P. Dinesha, S. Kumar and M. A. Rosen, "Combined effects of water emulsion and diethyl ether additive on combustion performance and emissions of a compression ignition engine using biodiesel blends,," *Energy,* vol. 179, pp. 928-937, 2019.

[24] H. Venu, L. Subramani and V. D. Raju, "Emission reduction in a DI diesel engine using exhaust gas recirculation (EGR) of palm biodiesel blended with TiO2 nano additives," *Renewable Energy,* vol. 140, pp. 245-263, 2019.

[25] I. Örs, S. Sarıkoç, A. E. Atabani, S. Ünalan and S. O. Akansu, "The effects on performance, combustion and emission characteristics of DICI engine fuelled with TiO2 nanoparticles addition in diesel/biodiesel/n-butanol blends,," *Fuel,* vol. 234, pp. 177-188, 2018.

[26] A. Praveen, G. L. N. Rao and B. Balakrishna, "Performance and emission characteristics of a diesel engine using Calophyllum Inophyllum biodiesel blends with TiO2 nanoadditives and EGR,," *Egyptian Journal of Petroleum,,* vol. 27, no. 4, pp. 731-738, 2018.

[27] V. K. Nema and A. Singh, "Emission Reduction in a Dual Blend Biodiesel Fuelled CI Engine using Nano-Fuel Additives,," *Materials Today,* vol. 5, no. 9 Part 3, pp. 20754-20759, 2018.