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Performance and Emission Characteristics of C.I Engine with Composition of Cobalt Aluminium Oxide as Additive to Diesel

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Abstract : The objective is to integrate nanoparticles with fuels such as diesel, biodiesel, a plastic fuels, etc. to increase the fuel efficiency. The metal oxide nanoparticles will reduce the carbon monoxide emissions by donating oxygen atoms from their lattices to catalyze the combustion reactions and to aid complete combustion; due to this, there will be an increase in the calorific value of the blend (fuel + nanoparticles). The size of the particles to be 20 to 30nm for aluminum oxide and cobalt oxide nanoparticles respectively. These nanoparticles have been synthesized by using ultrasonicator. Different concentration blends- 250, 500, 750ppm were prepared by adding the required weight of metal oxides in 1 liter of diesel and sonicating for an hour. The blend properties- calorific value, viscosity, and flash point were determined. The engine was loaded with different brake power with each blend of the diesel-fuel additive. The significant improvement in brake thermal efficiency, brake specific fuel consumption, and exhaust gas temperature is observed.
Keywords : Aluminum Oxide, Cobalt Oxide, CI Engine, Performance, Emission.

Introduction

The Nano additives act as combustion catalyst which reduces delay period and promotes complete combustion when added to base fuel and hence increases the efficiency of the engine and lowers brake specific fuel consumption. The activation energy of nanoparticles burns off carbon deposits within combustion chamber which lower HC, NOx and smoke emission. The current investigation to combining metal oxide nanoparticles with diesel as additives to accelerate combustion rates, boost calorific values, reduce ignition delay, and engine performance has been studied.

Cobalt oxide – The oxygen atoms in cobalt oxide particles can moderate the combustion reactions. As results, the combustion was cleaner when using the cobalt additive, and emission of CO and unburnt HC were reduced.

Aluminium oxide – Its can used to increase the power output of engines, due to its high combustion energy.

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Literature Study

Ahmed I. EL-Seesy et al. [1] studied the Influence of nanoparticles additives into Jojoba Biodiesel and Diesel on Diesel Engine to analysis Performance and Emissions. In this nano-particles of size from 10 to 15nm with tube length 1-10microns, the dose level is varied from 10 to 50mg/l blend with diesel by using ultrasonicator. Results best mechanical performance has been obtained at nano dose level of 50mg/l, while the best environmental performance is recorded at a dose level of 20mg/l. Finally, they concluded, that valuable to recommend dose level is 40mg/l where reasonable improvement in engine performance is achieved.

Ali M.A. Attia et al. [2] had been analyzed the effects of alumina nanoparticles additives into jojoba oil-diesel mixture on diesel engine performance. 20% biodiesel and 80% diesel fuel with different doses from 10 up to 50mg/l of the alumina nanoparticles mixture are homogenized with an ultrasonicator mixer. Results of all doses, the overall BSFC is reduced by about 6%, engine thermal efficiency is increased up to 7%, and all engine emissions have been reduced (NOx about 70%, CO about 75%, smoke opacity about 5%, and UHC about 55%). It was found that to optimize engine performance is about 30mg/l blended with 20% biodiesel is used.

Amit et al. [3] had been evaluated the impact on the performance of CI engine in 10 to 60% of jatropha biodiesel in mixed proportion from 10 to 60ppm of cobalt oxide and iron oxide nanoparticle with size 30-70nm. JBD+40ppmFe2O3+40ppmCe3O4 fuel is tested and gives, higher brake thermal efficiency (32.5%) is observed, which is greater than the brake thermal efficiency of neat diesel (32%) and improved BSFC (0.270kg/kWh) as compare to neat diesel (0.280kg/kWh) and reduced exhaust gas temperature(245°C) as compare to neat diesel(310°C).

Anbarasu G et al. [4] had been analyzed the effects of nano-additives on performance and emission characteristics of Calophyllum innophyllum biodiesel. The obtained particle size range in below 100nm, the nanoparticles (150mg/l) were dispersed in the biodiesel (B100CO3O4 and B100TiO2) blend by a Ultrasonicator and Magnetic stirrer for 2 hours. According to the results of this experiment, the brake thermal efficiency was increased with nano-additives and a problem was found that high NOx emission.

Arul Mozhi Selvan V et al. [5] objective to establish the performance and emission characteristics of a compression ignition engine while using cerium oxide nanoparticles as an additive in neat diesel and diesel-biodiesel-ethanol blends. The cerium oxide nanoparticles size 32nm in the mixture of 70%Diesel +10%Biodiesel+20%Ethanol+25ppmCeO3 as results increase in ignition delay and brake thermal efficiency while in emission there will gradually decrease in carbon monoxide, HC, NO emission, and smoke.

Asaithambi.K et al. [6] premeditated the performance and emission characteristics of a diesel engine using Gadolinium oxide nanoparticles as additive particles are weighed to a predefined mass fraction from 10 to 70ppm and dispersed in the diesel with the aid of ultrasonicator set at a frequency of 20 kHz for 15-30minutes. The results, improves engine performance (increasing BTE and decreasing SFC) but also increase in NOx emissions and then is lower in HC, CO, and Smoke.

Jayanthi P et al., [7] performed experiments were conducted to study the effect of copper oxide added to biodiesel on performance and emission characteristics of a direct injection diesel engine operated at a constant speed of 1500 rpm at different operating conditions. The metal-based copper oxide nanoparticles additive was added to biodiesel at a dosage of 40 ppm, 80 ppm and 120 ppm with the aid of an ultrasonicator. Results show that copper oxide additive is effective in control of HC, CO, smoke, and NOx at full load conditions. Finally, they concluded a maximum increase in brake thermal efficiency was found to be B20+ 80 ppm CuO and also reduces specific fuel consumption at full load conditions.

Jothi Thirumal.B et al. [8] experimental investigate on the influence of the addition of cerium oxide in a diesel engine. The additives made Diesel + CeO25 ppm and Diesel + CeO50 ppm was agitated for about 30 min in an ultrasonicator to obtain a stable nano fuel. Finally, they concluded CeO450ppm improve the BTE to be 6% higher than diesel. Whereas emissions such as NOx, smoke, CO, and HC were observed to be 62.7%, 15%, 35.65%, and 56.5% lower than diesel at full load condition.

Kale N W et al. [9] performed an experimental investigation on single cylinder diesel engine fuelled with cottonseed biodiesel blends with nano-additives. The Nano additives (Al2O3) were mixed with the fuel

blend in the mass fraction of B20, B30, B20Al2O350ppm, B20Al2O3100ppm, B30Al2O350ppm and B30Al2O3100ppm by means of Ultrasonicator which was set at frequency 40 kHz for 30minutes. Finally, they concluded best engine performance and environmental performance were obtained when diesel, bio-diesel and its blend of nano-additives.

Karthikeyan S et al. [10] had studied the role Al2O3 nano additive in GSOME (grapeseed oil methyl ester) Biodiesel on the working characteristics of a CI engine. The fuel properties of D80B20, D80B20Al2O350ppm, and D80B20Al2O3100ppm have been placed in an ultrasonicator set at a frequency of 40kHz and 120W for 60min. finally, they concluded best engine performance and environmental performance occurred while the addition of 50ppmAl2O3.

Karthikeyan S et al. [11] investigated the diesel engine performance and emission analysis using canola oil methyl ester with the nano-sized zinc oxide particles. The fuel blend in various fraction such as D80B20, D80B20ZnO50ppm, and D80B20ZnO100ppm have been placed in an ultrasonicator set at a frequency of 40kHz and 120W for 60min. from that they concluded best engine performance and environmental performance occurred while the addition of 50ppmZnO.

Karthikeyan S et al. [12] analyzed the environmental effect of CeO2 nano additive on performance and emission reduction in a COME operated CI marine engine. The fuel blend in various fraction such as 80%D+20%B, 80%D+20%B+50ppmCeO2 and 80%D+20%B+100ppm CeO2 have been placed in an ultrasonicator set at a frequency of 40 kHz and 120W for 60min. As results, best engine performance and environmental performance occurred while the addition of 50ppmCeO2.

Kasireddy Sravani et al. [13] analyzed the Performance and Emission Characteristics of CI Engine When Fuelled with Pongamia Biodiesel and Zinc Oxide Nano Fluid as Additive in various B20, B20+40ppm, B20+80ppm, and B20+120ppm. Finally, they concluded B20+80ppm fuel given minimum emission valve.Remaining fuel blends are B20, B20+40ppm and B20+120ppm increased when compared with diesel.

Kevin kunnassery et al. [14] analyzed on emission characteristics from a CI engine using nanoparticles as additives in various blends from 10ppm to 40ppm CeO2 with diesel. As results, D+CeO230ppm fuel blend was given us an enhancement efficiency by 30% of that of neat diesel.

Madhan Raj et al. [15] investigated on Aluminium oxide nanoparticles blended diesel fuel combustion, performance and emission characteristics of a diesel engine using diesel fuel. Fuel blended in various mass fractions of DF+Al2O325ppm and DF+Al2O350ppm respectively with the help of a sonicator. The results also showed a considerable enhancement in brake thermal efficiency due to the influence of Al2O3 nanoparticles addition in diesel blend. As the dosage level of 50 ppmAl2O3 nanoparticles increases the brake thermal efficiency and decreases the HC, CO and NOx emissions compared to 25ppm of Al2O3 nanoparticles blend.

Mu-Jung Kao et al. [16] significant chemical reaction of hydrogen combustion during aqueous Aluminium Nanofluid combustion in diesel fuel. The average diameter of the Aluminium nanoparticles is about 40–60 nm added from 30 cc to 50 cc into 1 liter of diesel fuel, and then an ultrasonic vibrator is used to vibrate the mixture for 15 min to form the experimental nano-Aluminium diesel fuel. The results show that Brake specific fuel consumption for Al+Diesel fuel is less than the Diesel fuel at 1800rpm engine speed. The Aluminium Nanopowder additive mixed in D fuel causes a clear smoke reduction and for engine speeds less than 1800 r /min the NOx concentration has also a decreasing tendency.

Nagaraj Banapurmath et al. [17] Effect of silver nano-particle blended biodiesel and swirl on the performance of diesel engine combustion. The biodiesel was prepared from a honge oil called Honge Oil Methyl Ester [HOME]. The mass fractions of silver nanoparticles with HOME is 25ppm and 50ppm using ultrasonicator with help of mechanical homogenizer. As results there maximum brake thermal efficiency was obtained for HOME+50SILVER with reduced harmful pollutants compared to HOME+25SILVER blends.

Nallusamy et al. [18] premeditated the experimental analysis on Nano lubricants used in multi-cylinder petrol engine with copper oxide as nanoparticle and SAE15W40 commercial engine oil and punga oil as biodegradable oil used. From the results, SAE15W40 with CuO Nano lubricant have good anti-wear properties with wear scar diameter of 0.13 mm. But punga oil with CuO has better anti-friction properties than

SAE15W40-CuO lubricant. Conclusively, SAE 15W40 with 0.1% CuO Nano lubricant is suitable for enhanced performance in multi-cylinder petrol engines.

Narinder Singh et al. [19] inspected the effect of CNT-Emulsified fuel on performance emission and combustion characteristics of a four-stroke diesel engine. Carbon nanotubes are produced by indigenous flame synthesis method. Water diesel emulsion prepared in the proportion of 83% diesel, 15% water, and 2% surfactant is used. Tween 80 and Span 80 are used as surfactants with an HLB balance of 8. CNT in the mass fraction of 50ppm, 100ppm and 150ppm are blended in the water-diesel emulsion. CNT is dispersed in the water for 35 minutes with the help of ultrasonicator set at a frequency of 40 kHz at 120W. The test results revealed that water diesel emulsion (15% water) can be used as a fuel in a diesel engine with no engine modification. Adding CNT to reducing the emission, improving the performance and combustion characteristics.

Nishant Mohan et al. [20] Experimental investigation was carried out to study the engine performance and emission parameters of a single-cylinder Compression Ignition (CI) engine using nano fuels which were formulated by sonicating nanoparticles of Aluminium in base diesel. As results, the performance at higher loads revealed a drop in peak cylinder pressures and reduction of 7% in specificfuel consumption as compared to diesel. Improved combustion rates raised exhaust gas temperatures by 8% leading to increased brake thermal efficiency by 9%, as compared to diesel at maximum loading conditions. As well as in emission 25 to 40% reduce CO, 8% reduce in unburnt hydrocarbon. However, elevated temperatures resulted in a marginal rise in NOx emission.

Nithin Samuel et al. [21] in this study the main objective is a too experimental investigation is carried out to establish the performance and emission characteristics of a compression ignition engine while using cerium oxide nanoparticles as an additive with neat diesel. As results, cerium oxide acts as an oxygen donating catalyst which reduces oxygen for the oxidation of CO or absorbs oxygen for the reduction of NOx.

Pallavi Ghogare et al. [22] determined the performance, emission and combustion characteristics of diesel engine fuelled with biodiesel blends with the Nano Additives (Al2O3) were mixed with the fuel blend in the mass fraction of B20, B30, B20Al2O350ppm, B20Al2O3100ppm, B30Al2O350ppm, and B30Al2O3100 ppm by means of an ultrasonicator which was set at frequency 40 kHz. Finally, they concluded that Brake thermal efficiency increases when its blends with Nano additives (Al2O3) at 25% of load blend B20 gives higher brake thermal efficiency and the value is 20.4%.The lowest value of air-fuel ratio at full load condition occurs with the blend B20+50ppmAl2O3 and the value is 19.7.

Prabhu L et al. [23] investigated on performance and emission analysis of TiO2 nanoparticle as an additive for bio-diesel blends in 250ppm and 500ppm of titanium oxide nanoparticles is blended with 20% biodiesel-diesel blend (B20). These blends are subjected to high-speed blending followed by ultrasonic bath stabilization that improves the stability of the blends. The results indicated that the brake thermal efficiency was increased and carbon monoxide (CO), hydrocarbon (HC) and smoke emissions were decreased while the NO emissions were increased marginally for 250ppm nanoparticle added with B20 blends when compared with B20 and 500ppm added with B20 fuel at full load at full load conditions.

Prabu Arockiasamy et al. [24] analyzed Performance, Combustion and Emission Characteristics of a Diesel Engine Fuelled with Nanoparticle Blended Jatropha Biodiesel. The preparation of fuel 30ppm of alumina nanoparticle is blended with 1 liter of neat biodiesel and another fuel 30ppm of cerium oxide nanoparticle is blended with 1 liter of neat biodiesel both are ultra-sonicated at the 50Hz frequency for 30 minutes. For JBD30A test fuel - Percentage reduction of NO by 9%, Unburned HC by 33 %, CO by 20 % and smoke opacity by 17 % are observed when compared to neat biodiesel. For JBD30C test fuel - Percentage reduction of NO by 7%, Unburned HC by 28%, CO by 20% and smoke opacity by 20% are observed when compared to neat biodiesel. 3.5% increase in BTE is observed for both the JBD30A and JBD30C test fuels compared to neat biodiesel.

Raja et al. [25] investigated the effect of heat transfer enhancement and NOx emission using Al2O3/water nano fuel as a coolant in CI engine. Nanofluids are prepared using the two-step method with various volume concentrations of 0.5, 1, 1.5 and 2% Al2O3. The investigation shows that using nanofluids resulted in 12.5% reduction of NOx emissions at full load and about 3-5% at no load and part load.

Ramarao et al. [26] had been an experimental investigation on performance and emission characteristics of a single cylinder diesel engine using nano-additives in diesel and biodiesel. The fuel was prepared at blends in different proportions of B20, B50, B20+0.04gmCeO2, B50+0.04gmCeO2, B20+0.08gmCeO2, B50+0.08gmCeO2. As results NOx emissions with cottonseed oil and their dif¬ferent blend accept B20+0.04gmCeO2 and B20+0.08gmCeO2 with the addition of Nano additive decrease as compared to diesel fuel.

Ramesh Babu et al. [27] experimental investigation to establish the performance, emission and combustion characteristics of a diesel engine using diesel fuel and alumina-nanoparticle blended diesel fuel. The nanoparticles of alumina are mixed with the diesel fuel in the mass fractions of D+25ppmAl, D+50ppmAl, and D+75ppmAl respectively. The observations are as follows. The thermal efficiency of a modified diesel is higher than pure diesel at all the loads. The NOX emission is lower for diesel- alumina blends than neat diesel. The smoke opacity decreases with the diesel - alumina blends. The addition of Aluminium oxide nanoparticles in neat diesel proportionately decreases the smoke further.

Rao S.C et al. [28] investigated the performance analysis of DI diesel engine fuelled with diesel along with nano additives in the proportions of D+250ppmZnO, D+500ppmZnO, D+40ppmCeO2, D+80ppmCeO2, The engine test results showed that brake specific fuel consumption of zinc oxide 250 ppm blend is nearly same as cerium oxide 40 ppm and also zinc oxide 500 ppm blend is nearly same as cerium oxide 80ppm at higher loads, and also it is observed that all the nanoparticle added blends are having less exhaust temperature than the diesel values at higher load. As results, smoke was decreased in 40 ppm of CeO2 blend fuel.

Rolvin D'Silva et al. [29] in this study the main objective is made to use titanium dioxide and calcium carbonate nanoparticles as a fuel additive in a C.I. Engine. Dispersion of nanoparticles in B20 methyl ester of Pongamia oil is carried out using a probe sonicator. Results reveal that brake thermal efficiency of the engine is improved by 2% with the use of TiO2 nanoparticles in B20 blend when compared with fuel sample without nano-additives andsimilarly 6% reduction in BSFC value is observed for TiO2 nano fuel in comparison to plain oil. It is observed that the blend B20 with TiO2 nanoparticles result in an average 16% lesser smoke emission compared to plain B20.

Santhanamuthu M et al. [30] evaluation of CI engine performance fuelled by Diesel-Polanga oil blends doped with iron oxide nanoparticles Iron oxide nanoparticles was added in three different concentrations viz., 100, 200 and 300 ppm levels in all the three polanga oil – diesel fuel blends to study their effects on engine performance. The engine was loaded with five different brake powers for each polanga oil – diesel – iron oxide nanoparticle fuel blends. It was observed that the presence of iron oxide nanoparticle reduces the ill effects of polanga oil in diesel. At 25% polanga oil blend with diesel and iron oxide nanoparticles concentration of 150 ppm, the engine performance was observed to be similar to that of running on neat diesel.

Selvaganapthy A et al. [31] has been analyzed the possible effects of adding nano particles with diesel to improve the efficiency of the diesel engine. In case of diesel blended with DF+ZnO250ppm and DF+ZnO500ppm. As the founded ignition delay reduced, peak pressure and heat release rate increased. The result concluded that brake thermal efficiency increased minutely. As a drawback, it was also found that the emissions NOx, increased.

Senthilraja et al. [32] effects of specific fuel consumption and Exhaust Emissions of a four-stroke diesel engine with CuO/water Nanofluid as a coolant. The CuO nanoparticles of 27 nm were used to prepare three different volume concentrations (i.e. 0.05%, 0.1%, and 0.2%) of CuO/water nanofluids were prepared by using two-step method. The experimental results revealed that, at full load condition, the specific fuel consumption was reduced by 8.6%, 15.1% and 21.1% for the addition of 0.05%, 0.1% and 0.2% CuO nanoparticles with water, respectively. Also, the emission tests were concluded that 881ppm, 853ppm, and 833ppm of NOx emissions were observed at high load with 0.05%, 0.1% and 0.2% volume concentrations of CuO/water nanofluids, respectively.

Sungyong Park et al. [33] enactment of an Emission characteristics of exhaust gases and nanoparticles from a diesel engine with biodiesel-diesel blended fuel (BD20). The nanoparticles in the size range between 10.6nm and 385nm were reduced by about 10% and 25%, respectively when going from D100 to BD20. The particle number and mass of both fuels were reduced by about 43% when going from with EGR to without

EGR. When EGR was applied in the engine system, the particle number and mass were reduced by 24%, and 16%, respectively, when going from D100 to BD20.

Sunilkumar et al. [34] investigated the Performance and Emission Characteristics of Graphene Nano Particle-Biodiesel Blends Fuelled Diesel Engine. The biodiesel was prepared from Waste Cooking Oil Methyl Ester (WCOME). The graphene nanoparticles were blended with the biodiesel fuel in the mass fractions of 20ppm, 40ppm and 60ppm with the aid of an ultrasonicator. As results higher dosage of nanoparticle addition i.e. 60 ppm to WCOME might further increase the diesel engine performance.

Suresh Y et al., [35] investigated the performance test of CI engine are conducted for different curcas nut bio-diesel blends with the nanoparticle. Curcas nut seed is chosen for biodiesel production and Cobalt oxide nanoparticle experiment is conducted for B10, B20 and B30 with 75mg Cobalt oxide nanoparticles. The engine experimental results that efficiency including thermal efficiency is 2% increased and mechanical efficiency was reduced by 2% for biodiesel blend with the nanoparticle. However, a slight increase in specific fuel consumption was experienced for biodiesel mixture with the nanoparticle.

Syed Aalam et al. [36] Experimental investigations on a CRDI system assisted diesel engine fuelled with Aluminium oxide nanoparticles blended biodiesel in mass fractions of ZJME25, ZJME25+25ppmAl2O3, and ZJME25+50ppmAl2O3 with the help of a mechanical Homogenizer and an ultrasonicator. As results shows that great improvement in brake thermal efficiency and heat release rate due to the impact of Al2O3 nanoparticles blends with biodiesel-diesel fuel. Overall, it was clear that the Aluminium oxide nanoparticles (Al2O3) are effective in improving the properties of the biodiesel blend.

Venkatesan SP et al. [37] had been Experimently investigated was carried out to determine combustion, performance and emissions characteristics of a diesel engine using nano-Aluminium oxide mixed with diesel. Then- Al2O3 of size 40 nm was mixed into diesel fuel at the rate of 1g/l and 1.5g/l for formulation was dispersed by means of an ultrasonic vibrator in order to produce a uniform dispersion. As results gradually increase in the brake thermal efficiency and substantial reduction in content of NOX and unburnt hydrocarbon (UBHC) at all the loads compared to neat diesel.

Vishwajit A. Bhagwat et al. [38] inspected the use of graphene nanoparticle – biodiesel blend diesel engine was fuelled in mass fractions of Honge Oil Methyl Ester [HOME], HOME25, HOME 25+25 ppm graphene and HOME25+50ppmgraphene with the help of a mechanical Homogenizer and an ultrasonicator. However, HOME performance was improved by adding nanoparticles. The brake thermal efficiency of HOME50GRAPHENE NPs blended fuel was higher compared to that of HOME25GRAPHENE blends due to higher dosing level graphene nanoparticles to biodiesel.

From this Literature reviews:

The properties of cobalt oxide and Aluminium oxide are concluded below points:

- Cobalt oxide – 25ppm to 60ppm

Results:

- ✓ Increases in Performance.
- ✓ But more effect on emission characteristics such as:

- NO_x emission slightly increases,
- CO emission decreases,
- Smoke opacity is lower and
- UHC decreases.

- Aluminium oxide – 50ppm to 100ppm

Results:

- ✓ Performance characteristics such as:

- Brake Thermal Efficiency is increases
- Brake Specific fuel consumption is increased.
- But not more effect on emission slightly decreases in CO, HC, and NO_x.

Conclusion

It was found from the literature study made, many alternatives fuel composition with nanoparticles have been analyzed using CI engine. It was found that the Aluminium oxide can use to increase the power output of engines, due to its high combustion energy and Cobalt oxide having higher oxygen atoms which can moderate the combustion reactions and especially to control the emission. The main objective of this work is to improve combustion performance and reduction in emission of CO, NO_x and unburnt HC.

References

1. Ahmed I. EL-Seesya,, Ali K. Abdel-Rahmana, Mahmoud Badya, and S. Ookawara, 2016, "Influence of Multi-Walled Carbon Nanotubes Additives into Non-Edible Biodiesel-Diesel Fuel Blend on Diesel Engine Performance and Emissions", Elsevier, Vol.8, No.12, pp.166 – 172.
2. Ali M.A. Attia, Ahmed I. El-Seesy, Hesham M. El-Batsh and Mohamed S. Shehata, 2014, "Effects of alumina nanoparticles additives into jojoba methyl ester-diesel mixture on diesel Engine performance", ASME International Mechanical Engineering Congress and Exposition (IMECE), Vol.4, No.9, pp.247-25.
3. Amit and Sudhir Kumar, 2015, "Impact on the performance of direct compression ignition engine by adding nano-particle in biodiesel", Journal of Material Science and Mechanical Engineering (JMSME), Vol.2, No.7, pp.7-9.
4. Anbarasu G, Jeryrajkumar L and Elangovan T, 2016, "Effects on nano additives on performance and emission characteristics of calophyllim inophyllum biodiesel", International Journal of Chem Tech Research (IJCTR), Vol.9, No.4, pp.210-219.
5. Arul Mozhi Selvan V, Anand R B and Udayakumar M, 2009, "Effects of cerium oxide nanoparticle addition in diesel and diesel-biodiesel-ethanol blends on the performance and emission characteristics of a CI engine", ARPN Journal of Engineering and Applied Sciences, Vol.4, No.7, pp.819-825.
6. K.Asaithambi and S. Sivaprakasam, 2017, "Performance and Emission characteristics of Diesel Engine Using Nano Additive", International Journal of Advance Engineering and Research Development, Vol.4, No.1, pp.156-59.
7. Jayanthi P and Srinivasa Rao M, 2016, "Effects of nanoparticles additives on performance and emissions characteristics of a di diesel engine fuelled with biodiesel", International Journal of Advances in Engineering & Technology, Vol.9, No.6, pp.689-695.
8. B. Jothi Thirumal1, E. James Gunasekaran, Loganathan and C. G. Saravanan, 2015, "Emission reduction from a diesel engine fueled by cerium oxide nano-additives using SCR with different metal oxides coated catalytic converter", Journal of Engineering Science and Technology, Vol.10, No.11, pp.1404 -1421.
9. Dr. N. W. Kale and Pallavi Ghogare, 2016, "Experimental Investigation on Single Cylinder Diesel Engine Fuelled With Cotton Seed Biodiesel Blends With Nano Additives", International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Vol.8, No.2, pp.17-22.
10. S.Karthikeyan, A.Elango, S M Silaimani and A Prathima, 2014, "Role of Al_2O_3 nano additive in GSO Biodiesel on the working characteristics of a CI engine", Indian journal of chemical technology, Vol.21, No.2, pp.285-289.
11. S.Karthikeyan, A.Elango and A Prathima, 2014, "Diesel engine performance and emission analysis using canola oil methyl ester with the nano sized zinc oxide particles", Indian journal of chemical technology, Vol.21, No.2, pp.83-87.
12. S.Karthikeyan, A Prathima, A.Elango and K.Sabariswaran, 2014, "Enviroment effect of CeO_2 nano additive on performance and emission reduction in a COME operated CI marine engine", Indian journal of chemical technology, Vol.45, No.1, pp.167-172.
13. Kasireddy Sravani and G. Ravindra Reddy, 2016, "Performance and Emission Characteristics of CI Engine When Fuelled with Pongamia Biodiesel and Zinc Oxide Nano Fluid as Additive", International Journal of Engineering Research & Technology (IJERT) Vol.5, No.5, pp.684-687.

14. Kevin kunnassery, Sameer jackeray and suprabhat A Mohad, 2015, "Analysis on emission characteristics from a CI engine using Nano particles as a fuel additives", international journal of latest trends in engineering and technology (IJLTET), Vol.6, No.2, pp.80-89.
15. N. Madhan Raj, M. Gajendiran, K. Pitchandi1 and N. Nallusamy, 2016, "Investigation on Aluminium oxide nano particles blended diesel fuel combustion, performance and emission characteristics of a diesel engine", Journal of Chemical and Pharmaceutical Research, Vol.8, No.3, pp.246-257.
16. Mu-Jung Kao,Chen-Ching Ting,Bai-Fu Linand Tsing-Tshih Tsung, "Aqueous Aluminium Nanofluid Combustion in Diesel Fuel", Journal of Testing and Evaluation, Vol. 36, No. 2, pp.1-5.
17. Nagaraj Banapurmath, T.Narasimhalu, Anand Hunshyal, Radhakrishnan Sankaran, Mohammad Hussain Rabinal, Narasimhan Ayachit and Rohan Kittur, 2014, "Effect of silver nano-particle blended biodiesel and swirl on the performance of diesel engine combustion", International Journal of Sustainable and Green Energy, Vol.3, No.6, pp.150-157.
18. S. Nallusamy and J. Logeshwaran, 2017, "Experimental analysis on Nano lubricants used in multi cylinder petrol engine with copper oxide as nanoparticle" RAsayan J.Chem., Vol.10, No.3, pp.1050-1055.
19. Narinder Singh and R S Bharj, 2015, "Effect of CNT-Emulsified Fuel on Performance Emission and Combustion Characteristics of Four Stroke Diesel Engine", International Journal of Current Engineering and Technology, Vol.5, No.1, pp.477-485.
20. Nishant Mohan, Mayank Sharma, R. C. Singh and R. K. Pandey, 2015, "Performance Study of Diesel Engine Using Nanofuel", International Journal of Advance Research and Innovation, Vol.3, No.4, pp.665-668.
21. Nithin Samuel and Muhammed Shefeek K, 2013, "Performance and emission characteristics of a C.I engine with cerium oxide nanoparticles as additive to diesel", International Journal of Science and Research (IJSR), Vol.4, No.7, pp.673-676.
22. Pallavi Ghogare and Dr. N .W. Kale, 2016, "Experimental investigation on single cylinder diesel engine fuelled with soya bean biodiesel blends with nano additives", (IJPRET), Vol.4, No.9, pp.247-25.
23. Prabhu L, Satish Kumar S, Andrerson A, and Rajan K, 2015, "Investigation on performance and emission analysis of TiO_2 nanoparticle as an additive for bio-diesel blends", Journal of Chemical and Pharmaceutical Sciences, Vol.9, No.7, pp.408-412.
24. Prabu Arockiasamy and Ramachandran Bhagavathiammal Anand, 2015, "Performance, Combustion and Emission Characteristics of a D.I. Diesel Engine Fuelled with Nanoparticle Blended Jatropha Biodiesel", Periodica Polytechnica Mechanical Engineering, Vol.59, No.2, pp.88-93.
25. M.Raja, R.Vijayan, S.Suresh and R.Vivekananthan, 2013, "Effect of heat transfer enhancement and NO_x emission using Al_2O_3/water Nanofluid as coolant in CI engine", International Journal of engineering & Materials sciences, Vol.20, No.2, pp.443-449.
26. K. Ramarao, C. J. Rao and D. Sreeramulu, 2015, "The Experimental Investigation on Performance and Emission Characteristics of a Single Cylinder Diesel Engine using Nano Additives in Diesel and Biodiesel", Indian Journal of Science and Technology, Vol.8, No.29, pp.1-9.
27. K.Ramesh Babu and R.Bharathi Raja, 2015, "Theoretical and experimental validation of performance and emission characteristics of nanoadditives blended diesel engine", URAME, Vol.3, Issue.5, pp.18-31.
28. Rao S.C and Srinivasa Rao, 2015, "Performance analysis of di diesel engine fuelled with diesel along with nano additives", International Journal of Engineering Trends and Technology (IJETT), Vol.24, No.2, pp.107-110.
29. Rolvin D'Silva, Vinoothan K, Binu K. G, Thirumaleshwara Bhat and Raju K, 2016, "Effect of titanium dioxide and calcium carbonate nanoadditives on the performance and emission characteristics of C.I. engine", Journal of Mechanical Engineering and Automation, Vol.5, No.6, pp.28-31.
30. M.Santhanamuthu, S.Chittibabu, T.Tamizharasan and T.P.Mani, 2014, "Evaluation of CI engine performance fuelled by Diesel-Polanga oil blends doped with iron oxide nanoparticles", International Journal of ChemTech Research, Vol.6, No.2, pp.1299-1308.
31. A.Selvaganapthy, A.Sundar, B.Kumaragurubaran and P.Gopal, 2013, "An Experimental Investigation to Study the Effects of Various Nano Particles with Diesel on Di Diesel Engine", ARPN Journal of Science and Technology, Vol.3, No.1, pp.112-15.
32. S. Senthilraja, K Ck. Vijayakumar and R.Gangadevi, 2017, "Effects of specific fuel consumption and exhaust emissions of four stroke diesel engine with CuO/water Nanofluid as coolant", Unauthenticated Journals, Vol.1, No.1, pp.111-121.

33. Sungyong Park, Hwanam Kim and Byungchul Choi, 2009, "Emission characteristics of exhaust gases and nanoparticles from a diesel engine with biodiesel-diesel blended fuel (BD20)", Springer, Vol.23, pp.2555~2564.
34. Sunilkumar T, G Manavendra, N. R. Banapurmath and Guruchethan A.M, 2017, "Performance and Emission Characteristics of Graphene Nano Particle-Biodiesel Blends Fuelled Diesel Engine", International Research Journal of Engineering and Technology (IRJET), Vol. 04, Issue: 10, pp.552-557.
35. Suresh Y, Suresh R and Anil Kumar B N, 2017, "Performance analysis of cobalt oxide nano particles in curcas nut bio-diesel blends in CI engine", International Conference on Current Trends in Engineering Science and Taechnology, (ICCTEST), Vol.1, No.42, pp.255-259.
36. Syed Aalam C, Saravana C.G and Kannan M, 2015, "Experimental investigations on a CRDI system assisted diesel engine fuelled with Aluminium oxide nanoparticles blended biodiesel", Alexandria Engineering Journal, Vol.2, No.54, pp.351-358.
37. S P Venkatesan, 2015, "Influence of Aluminum Oxide Nanoparticle Additive on Performance and Exhaust Emissions of Diesel Engine", American-Eurasian Journal of Scientific Research, Vol.10, No.2, pp.88-92.
38. Vishwajit A. Bhagwat, Chetan Pawar and N. R. Banapurmath, 2015, "Graphene Nanoparticle - Biodiesel Blended DieselEngine", International Journal of Engineering Research & Technology (IJERT), Vol.4, Issue 02, pp.75-78.

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