Effect of Nanoadditives on Biodiesel Performance and Emission Parameters: A Review

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ABSTRACT

The renewable energy source biodiesel has significant advantages over fossil fuels and diesel oil, making it a viable replacement. Many researchers are inventing new methods and ideas for preparing Biodiesel products and have also found that nanoadditive is one of the best alternatives that upgrade fuel properties. Thus, nanoadditive use is in recent demand because of its significant impact on emission reduction. Researchers have used many nanoadditives like TiO_2, SiO_2, CNT, GO, CeO_2, CuO etc.; some show very few changes, but some show magnificent changes. In this paper, a comparative study of nanoadditives is being done to determine the parameters that change by doping nano additive in biodiesel blends and found that mixing nanoadditives change the properties of biodiesel. Thus, many papers will be reviewed on how properties change and the changes in combustion, performance and emission characteristics. Further, we can compare nano additives that show the best result and fewer changes; thus, this will help researchers select the best nano additive for their experiments. In combustion characteristics increase in Cylinder Pressure, Heat Release Rate (HRR) and a decrease in Ignition Delay were founded. In Performance Characteristics doping nanoadditive increases BTE but reduces BSFC & EGT. The significant changes in emission characteristics include an increase in NOX and a decrease in CO, HC, CO_2, and smoke. Also, it was found that different nanoadditives showed different results and concluded that CNT and TiO_2 showed the best result, and thus they can be used in further experiments.

Keywords: Biodiesel, Nanoadditives, Combustion parameters, Performance parameters & Emission parameters

1 Introduction

The main prospect for making countries develop energy plays the most vital key role on cultural and economic fronts. Fossil fuels, including petrol, coal, and mineral oils, are primarily used to meet global energy needs; as a result, their supply is depleting rapidly. Also, we know that diesel engines are more suitable for transport due to their improved TE. This faster depletion of fossils and increasing exhaust gas emission (EGE) has led to a crucial problem. Now, researchers must find the best suitable alternative for it [1]. It has been reported that of the total global liquid fuel consumed from 2010-2040, 63% share is only for the transportation sector. Also, yearly, there is an increase in average energy consumption by 1.1% in the transport sector due to a higher rate of development in the motorization industry. Due to the vast growth of the motorization industry, it is observed that there is a high increase in harmful emissions on Earth. We have noted that 22% of the greenhouse gasses are exhausted through the transport sector. Emissions released from automobiles play a high role in air quality debilitation. So, we need to reduce emissions, which can be mainly achieved through transportation. Thus, researchers are finding cleaner renewable energy sources that can fulfil the needs of energy and environment loss [2]. From this, we learn that there is a high rate of energy consumption derived from fuels which is causing the depletion of fossil fuels. Also, harmful emissions are increasing that are responsible for global warming. Thus, this problem led researchers to find alternative strategies for energy production, and according to them, biofuel is one of

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the best possible substitutes. Now biofuel is a type of renewable energy fuel derived from biomass. 14% of the world's energy needs can be contributed through biomass [3]. Biofuels are the types of energy fuels that are extracted from biomass (organic source). Biomass is renewable organic material that comes from plants and animals that can be processed again and again. Different types of generations in biofuels can be categorized as First Generation of Biofuel, Second Generation of Biofuel, Third Generation of Biofuel& Fourth Generation of Biofuel, as shown in Figure 1. It includes the description of different types of generations of biofuels present in today's time [4]. So, we know that biodiesel is the best alternative for diesel engines derived from biomass; now, to enhance its properties and parameters, we can add nanoadditives to biodiesel. The primary purpose of adding nanoadditive is to get better combustion, performance and emission characteristics as nanoadditive works as a catalyst. It enhances the heat transfer rate (HTR), due to which reactions take place at a high rate and improves physical properties [5]. Nanoparticles improve properties due to their high energy density and catalytic activity with a high surface-to-volume ratio [6]. Researchers have used many nanoadditives to enhance their properties. Some of them are Carbon nanotubes (CNT_S), Aluminium Oxide (Al_2O_3), Bismuth Oxide (Bi_2O_3), Silicon Oxide (SiO_2), Copper Oxide (CuO), Cerium Oxide (CeO_2), Manganese Oxide (Mn_2O_3), Cobalt Oxide (CO_3O_4), Graphene Oxide (GO), Titanium Oxide (TiO_2), Zinc Oxide (ZnO_2), Ferrous Oxide (Fe_3O_4) etc. So, we will go through many research papers and find which nanoadditive shows the best result.

2 Literature Survey

This section examined a range of research publications in order to reach its conclusion. Ramakrishnan *et al.* [7] looked into the impact of single-walled Carbon Nano Tubes (CNT) on the emissions of diesel engines running on neem biodiesel. and compared the results to normally produced diesel. For all load levels, they found reductions in NO_x, HC, CO, and smoke emissions of 9.2%, 6.7%, 5.9%, and 7.8%. Performance, combustion, and emissions of castor oil biodiesel blends containing nanoadditives and hydrogen fuel were studied by Xia *et al.* [8]. Through the use of a CI engine, they achieved this. The researchers found that when the concentration of nanoparticles rose, brake thermal efficiency (BTE) increased while pollutant emissions, including CO, CO_2, and HC, decreased. They also discovered that incorporating hydrogen into combustion processes improves combustion efficiency. In order to determine the function of nano additions for biodiesel and diesel blended transportation fuels, Chandrasekaran V *et al.* [9] conducted studies. The 20MEOM fuel ratio was superior to other blends through experimentation. Then, using the sol-gel method, 50 ppm of copper oxide nano additions were blended with 20MEOM blended fuel used in the engine. The results show that compared to the 20MEOM blend at maximum load, the BTE rose by 2.19%. Additionally, there was a proper reduction in the smoke, CO, and HC emissions. When employing Jatropha biodiesel in a diesel engine, M.S. Gad and Jayaraj S compared nanoadditives on performance and emissions [10]. When CNTs, TiO_2, and Al_2O_3 were added to biodiesel blends with nano Al_2O_3 as J20Al100 at rates of 25, 50, and 100 ppm, respectively, the TE of those blends increased by a maximum of 6.5% when compared to all other fuels tested. Compared to all fuels, the CO and NO_x emissions from the J20C50 jatropha biodiesel blends with CNTs were reduced by 35% and 52%, respectively. Compared to all other fuels, the jatropha biodiesel blend containing TiO_2 (J20T25) significantly decreased the emissions of smoke and HC by around 22% and 50%, respectively. The jatropha biodiesel mixed with nanoparticles (J20Al100, J20T25, and J20C50) showed the greatest improvement in engine performance and emissions reduction compared to the other tested fuels. By adding two nanoadditives to the diesel-ethanol mixture, Hussain Vali and Marouf Wani [11] experimented with increasing the diesel engine's output and emission characteristics. Diesel-ethanol blend performance measures like BTE and BFSC improved after adding mixed nanoadditives (Al_2O_3 and TiO_2) at 50 ppm and 100 ppm concentrations. Using nanoadditives also resulted in lower NO_x, CO, and UBHC but higher emissions of CO_2. Karthikeyan S *et al.* [12] studied the performance of Caulerpa racemose algal oil biodiesel in a diesel engine. Higher HRR was noted when Bi_2O_3 was employed as nanoadditives in this work to test the combustion properties at different loads. When Bi_2O_3 is added to blends, combustion operates better, increasing heat release at cylinder peak pressures close to diesel operation. The B20 + 100 ppm blend exhibits short burning times, and adding Bi_2O_3 increases the blend's volatility and reduces viscosity, resulting in better atomization, vaporisation, and air-fuel mixing formation. Fayad & Hayder [13] investigated how butanol-diesel mixes with aluminium oxide nanoparticles affected the efficiency, emissions, and particulate characteristics of diesel engines. Aluminium oxide (Al_2O_3) nanoparticles were added to a butanol-diesel blend (B20) in three distinct concentrations—30, 50, and 100 mg/l in order to study their impacts on combustion, particulate matter, and emission characteristics. It was shown that adding Al_2O_3 raises the HRR and cylinder pressure by 6% and 13%, respectively. BTE increased by 4.7%, whilst BSFC decreased by 7.3%. Furthermore, there was a 42.71%, 37.46%, and 12.37% reduction in HC and NO_x emissions, respectively.

Gad *et al.* [14] tested biodiesel with carbon nanomaterials and graphene oxide to improve the performance, emissions, and combustion characteristics of diesel engines. It was discovered that there are improvements in TE for B20CNT100 and B20CNS100 at 8% and 19%, respectively, concerning B20 when different concentrations of CNTs and graphene nanosheets are blended with a biodiesel blend with a 20% volume percentage of biodiesel. The biggest reductions in smoke emissions, by 28% and 54%, were attained by biodiesel blends with 100 ppm concentrations of CNTs and graphene nanosheets, and the highest reductions in CO emissions, at approximately B20, were 27 and 47%, respectively. The largest decreases in NO_x emissions were 22 and 44%. However, regarding HC emissions, the biodiesel blend's B20CNT100 and B20CNS100 emissions were 28% and 52%, respectively. Peak cylinder pressure gains for B20CNT100 and B20CNS100 over B20 were 3 and 5.5%, although the biggest ignition delay improvements were 10 and 22% and 22%, respectively. The analysis of ternary fuel (diesel, biodiesel, and bioethanol) combined with metal-doped titanium oxide nano additives was experimented with by Janakiraman *et al.* [15] and tested on a diesel engine. It contains TiO_2 in concentrations ranging from 35 ppm to 65 ppm as a nanoadditive. Various studies on a diesel engine were conducted using the various TiO_2 concentrations mixed with ternary fuel mixes (70% diesel, 20% biodiesel, and 10% bioethanol). It was discovered that the best results were obtained when TiO_2 was added at 65 ppm because BTE decreased and BSFC increased. Combustion characteristics also improved as cylinder pressure increased and HRR decreased. Additionally, a decrease was seen in UBHC, CO, smoke, and NO_X. According to Manigandan *et al.* [16], the inclusion of CeO_2 and Al_2O_3 increases BTE by 4.3% and 2.5%, respectively, when compared in comparison research comparing TiO_2, CNT, Al_2O_3, CuO, and CeO_2 on the lowering of diesel engine emissions when operating on hydrogen fuel blends. However, there hasn't been any discernible variation in the amount of gasoline used for CeO_2's brakes. Compared to other mixes, the BSFCs of CNT and TiO_2 nanoparticles were 23% and 22% lower, respectively. According to studies on emission characteristics, the addition of hydrogen and nanoparticles greatly reduces the emission of carbon monoxide, carbon dioxide, and hydrocarbons. But the only material that produced an adequate NO_x emission result was CNT. Najafi [17] employed nanoparticles in biodiesel-diesel mixtures in his study on the combustion properties of diesel engines. He discovered that these blends burned more quickly and at a higher pressure than neat diesel fuel, increasing the peak pressure of the in-cylinder gases as well as the rate at which the peak pressure rose. Compared to clean diesel fuel, biodiesel and biodiesel with nano additives had greater HRRs during the diffusion combustion phase. The longer burning time and better diffusion combustion phase were caused by the mixed fuels' greater oxygen contents. The performance, combustion, and emission characteristics of diesel-biodiesel-ethanol mix in CI engines were studied by Prabakaran & Udhoji [18]. Additionally, the HRR, cylinder pressure, and BSFC were all increased. Compared to diesel, there was a reduction in BTE, NO_x, and smoke. When Al_2O_3 nanoparticles are added to biodiesel-diesel-ethanol mixes, peak pressure and HRR increase, according to experiments by Venu & Madhavan [19]. Along with increased levels of hydrocarbon (HC), carbon monoxide (CO), nitrogen oxides (NO_x), exhaust gas oxygen (EGO), combustion duration (CD), and ignition delay (ID), there were also higher levels of other pollutants. Aalam and Saravanan [20] studied the effects of Mahua biodiesel combined with nanometal oxide on CRDI diesel engines (ANPs) using aluminium oxide nanoparticles. Different concentrations of the Mahua biodiesel blend (MME20) were doped into the ANPs. Comparing the outcomes to those of neat diesel and Mahua biodiesel mix (MME20), it was discovered that the nanoparticles blended biodiesel had BTE and reduced hazardous emissions (such as CO, HC, and smoke). With a diesel engine using mixed biodiesel and a urea-SCR system, Mehregan and Mohammad [21] looked into the impact of nanoadditives on the emission parameters of the engine. Used frying oil was combined with 80% diesel in this investigation to make B20 blended biodiesel. As nanofuel additives, 25 and 50 ppm mass fractions of manganese oxide and cobalt oxide nanoparticles were used. As a result, compared to base fuel, the blended gasoline with nanoparticles had much better BTE and significantly lower NO_x and CO emissions. S. Karthikeyan and A. Prathima [22] used microalgae methyl ester with doped nano additions to investigate the effects of CI engines on the environment. The performance and emission properties of the blend samples were investigated using experimentally obtained values for items like density, viscosity, calorific value, etc. The trial's results showed that adding nanoparticles to a biodiesel blend and utilising it in diesel engines improved performance attributes and reduced exhaust pollutants. The effects of silicon dioxide (SiO_2) nanoadditives on the operating and emission characteristics of a diesel engine using soybean biodiesel were examined by R. S. Gavhane *et al.* [23]. Numerous petrol samples had their performance and emissions characteristics assessed under various loading scenarios. BTE and brake-specific fuel consumption (BSFC) was enhanced by 3.48–6.39% and 5.81–9.88%, respectively, by SiO_2 nanoadditives. Compared to SBME25 fuel blends, the emissions of smoke, hydrocarbons, and carbon monoxide (CO) all dropped by 10.1-23.54%, 20.56-27.5%, and 1.9-17.5%, respectively. The impact of a nanoadditive on neat biodiesel was studied in terms of emissions and performance by A. Rameshbabu and G. Senthilkumar [24]. It combined basic biodiesel with the nanoadditive titanium dioxide in different amounts. TiO_2 nanoparticles added to biodiesel emulsion fuel further lower the emissions of NO_x, HC, CO, and smoke by 11.2%, 6.2%, 8.4%, and 5.8% during peak load circumstances. When operating at full load, adding 50 ppm of TiO_2 nanoparticles increases the BTE and BSFC by 0.8% and 1.2%, respectively, above CSBD. TiO_2 nanoparticles improve BTE and BSFC at 100 ppm fuel by 1.1% and 1.5%, respectively, compared to CSBD for all load conditions. In order to better understand how CuO nanoparticles affected diesel engine operation, emission, and combustion parameters, Rastogi PM *et al.* [25] employed jojoba biodiesel mix (JB20) as fuel. According to the trial result, the BTE for JB20CN50 fuel was higher than the BTE for other jojoba biodiesel fuel samples. To determine the effect of the CuO nanoparticles, the combustion parameters, including ignition delay, HRR, and cylinder pressure, were also investigated. Additionally, the CO, smoke, and hydrocarbon emissions from JB20 engines were reduced using CuO nanoparticles. Abdulaziz *et al.* [26] looked into the engine performance and emission characteristics of using Candle nut and soap nut biodiesel as a substitute for regular petrol. It was found that adding nanoparticles to biodiesel blends significantly improved engine performance when the samples were blended with neat diesel at concentrations of 20%, 30%, and 40% (B20, B30, and B40), respectively. Nitrous oxide, carbon monoxide, and hydrocarbon emissions were dramatically decreased by incorporating nano alumina at higher concentrations. In the end, 30B samples of various biodiesel blends were more effective at reducing nitrous oxide, carbon monoxide, and hydrocarbon emissions. In their study, Jayaseelan *et al.* [27] described using candlenut biodiesel combined with varied concentrations of cerium

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oxide (CeO_2) nanoparticles in an engine with a variable compression ratio. Cerium oxide nanoparticles are introduced to B20 and B40 candlenut biodiesel blends at a concentration of 25 ppm in order to assess engine performance and emission levels. In contrast to B20, where the NO_x, HC, and smoke opacity have all marginally decreased, the results of B40 show an improvement in carbon monoxide. Biodiesel-diesel blends with additives consisting of graphene oxide (GO) nanoparticles were used by Hoseini S.S. *et al.* [28] to study the performance and emission characteristics of a CI engine. Oenothora biodiesel was a part of the B20 mixture. Three different fuel mixtures had 30, 60, and 90 ppm GO nanoparticle concentrations. It was established that the application of GO markedly increased power and EGT. The usage of GO nanoparticles also resulted in noticeably lower levels of CO (5%–22%) and UHCs (17%–26%. CO2 (7%–11%) and NO_x (4%–9%) emissions did go up slightly as a result of similar situations. In the end, it can be concluded that nanographene oxide is a good substitute fuel that may be added to blends of biodiesel made from Oenothera lamarckiana. A. Rameshbabu and G. Senthilkumar [29] investigated how nano additives on neat biodiesel affected emissions and performance. Titanium dioxide was added as a nano additive in varying concentrations to conventional biodiesel. TiO_2 nanoparticles reduce NO_x, HC, CO, and smoke emissions in biodiesel emulsion fuel by an additional 11.2%, 6.2%, 8.4%, and 5.8%, respectively, during peak load circumstances. TiO_2 nanoparticles at a concentration of 50 ppm increase the BTE and BSFC by 0.8% and 1.2%, respectively, compared to CSBD at full load. Under all load conditions, utilising TiO_2 nanoparticle inclusion at 100 ppm, fuel resulted in 1.1% and 1.5% improvements in BTE and BSFC over CSBD.

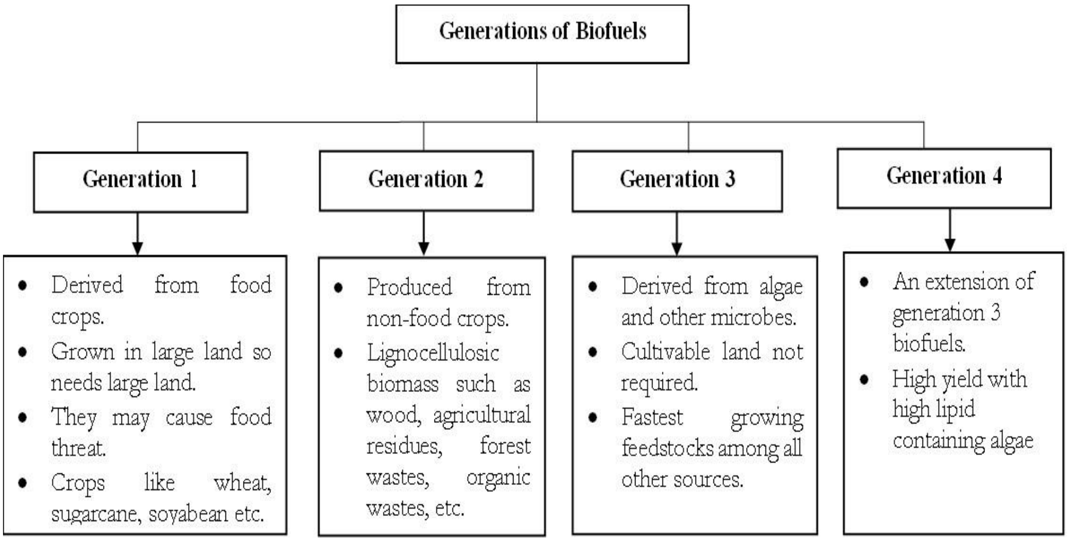

Figure 1: *Generations of biofuels*

3 Methodology

This context includes the discussion on the production of biodiesel, knowing the morphology of nanoadditives and making a blend of nanoadditives and biodiesel. The preparation of biodiesel can be represented using a flow chart in which we will get to know the process step by step, as shown in Figure 2.

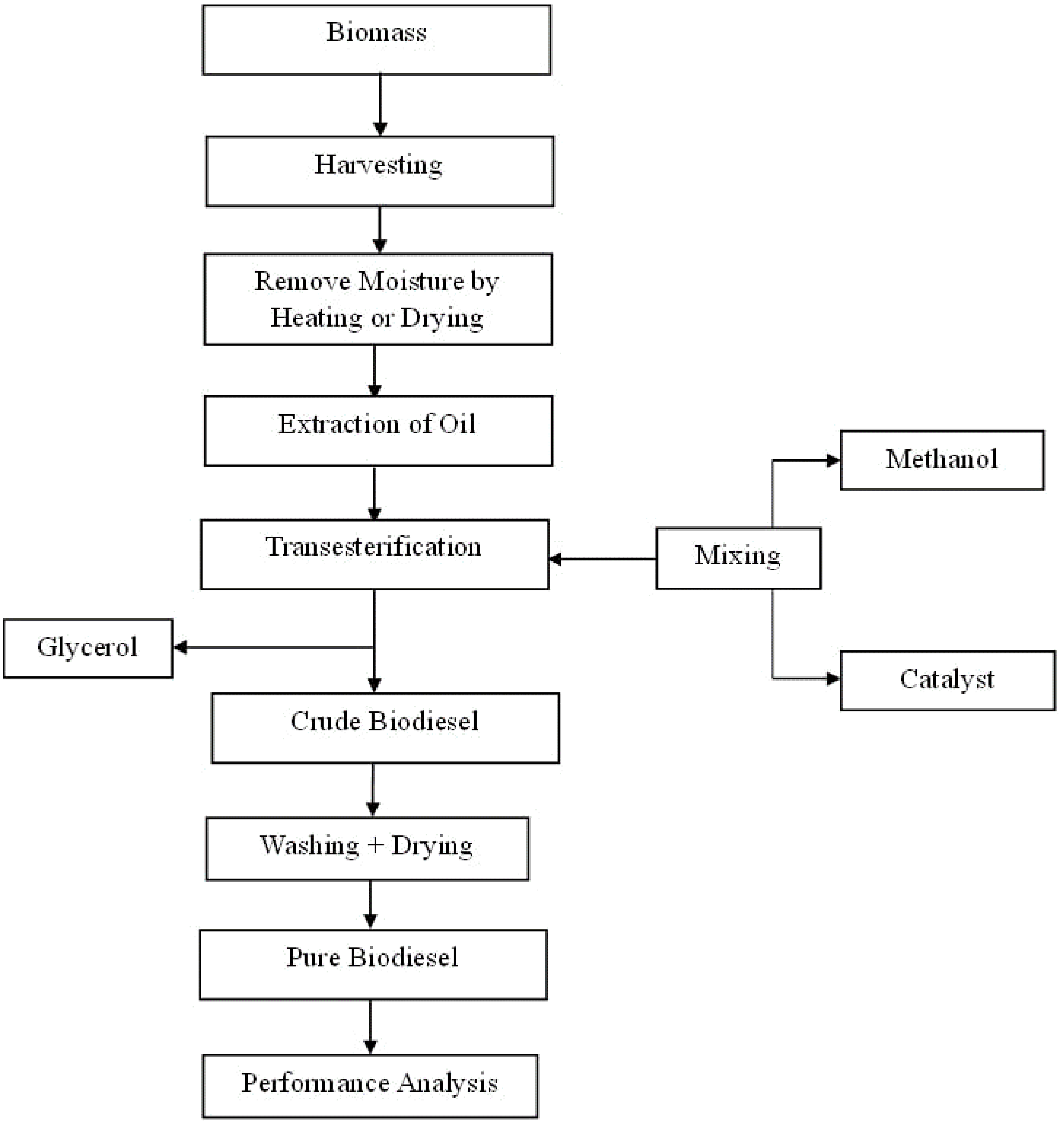

Figure 2: *Flow chart representation of the production of biodiesel blends*

3.1 Preparation of Biodiesel

Biodiesel is prepared from biomass (renewable organic material from plants and animals.) like Jatropha, cotton-seed, mahua, algae, waste cooking oil etc. So, firstly there is to harvest biomass and collect it in large quantities so that huge amounts of oil can be extracted. Then to make it efficient, its moisture is to be removed, which can be done in two ways Heating or Drying. When moisture is in a very large amount, then Heating is preferred; otherwise, Drying. Then by using the Soxhlet Apparatus, the extraction of oil is done. Now the oil extracted contains fats (as glycerol or ester) and biodiesel, so to separate them transesterification process is performed in which methanol is used as alcohol and KOH or NaOH as a catalyst. By performing this process, we get glycerol and crude biodiesel separately, which are further used, glycerol in beauty products, food, etc., and crude biodiesel used for making biodiesel. This crude biodiesel contains water, which can further cause a problem in diesel properties. Here, washing and drying are performed to remove the extra water and particles; thus, we get Pure Biodiesel. The process is shown in Figure 2.

3.2 Preparation of Biodiesel blends

After preparing biodiesel, we need to blend biodiesel and Pure Diesel because pure biodiesel does not yield good results. So, for best blend performance, analysis is done by adding B20D80, B35D65, B40D60 and so on. Effect on attributes (physical and chemical), performance characteristics (BTE, BSFC, EGT), emission characteristics (CO, HC, SMOKE, NO_X), and combustion characteristics (HRR, Ignition Delay, Cylinder Pressure) are the four main types of analysis performed. They claim that we receive the best blend, although the most popular blend is B20, which contains 6% to 20% biodiesel in addition to petroleum fuel. B20 denotes a blend of 80% pure diesel and 20% biodiesel.

3.3 Dispersion of Nanoadditives

Now, we observe a large amount of emission created when biodiesel and diesel blends are used. So, to reduce the emission of HC, CO, UHC, etc. and enhance other characteristics such as BTE, BSFC, HRR, EGT, and Ignition Delay, we use Nanoadditives. There are many nanoadditive. So, a comparative study is done to determine which is the best nanoadditive and thus, that nanoadditive is doped in the Biodiesel Blend. There are many nanoadditive such as CNT, Titanium Oxide, Silicon Oxide, Aluminium Oxide, Graphene oxide, Cerium Oxide, Copper Oxide, Zinc Oxide, MWCNT etc. Firstly, morphology characterization of nanoadditives is done, dispersion is done using different methods, and blends are formed. This whole process is represented as a flow chart in Figure 3.

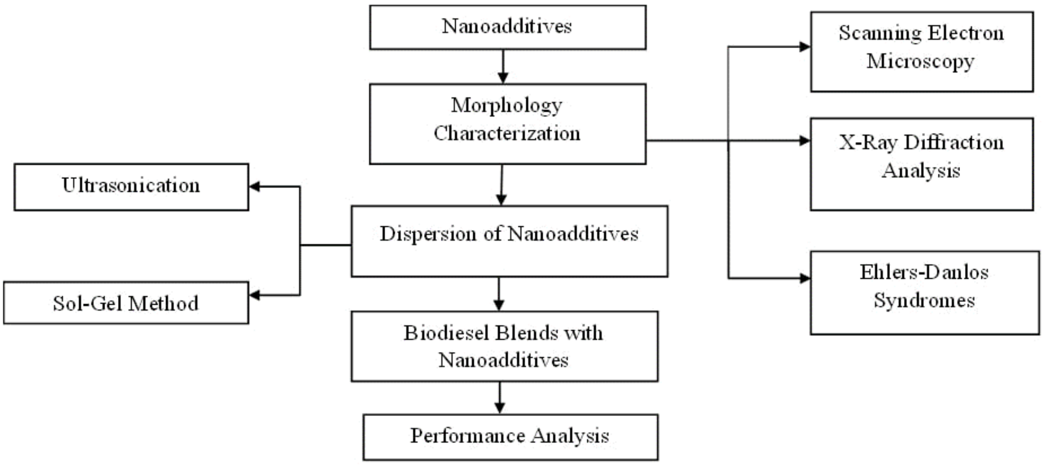

Figure 3: *Flow chart representation of the addition of nanoadditives in biodiesel*

4 Results and Discussion

This section will discuss the findings from several research and review publications. In this part, four parameters are mostly taken into account. First, there are changes in the density, kinematic viscosity, calorific value, cetane number, and other physical and chemical parameters. Changes to combustion properties such as HRR, in-cylinder pressure, and ignition delay constitute the second parameter. Changes in performance traits like BTE, BSFC, and exhaust gas temperature (EGT) are included in the third parameter. The fourth factor is the emission parameter, which includes CO, HC, UBHC, and NO_X.

4.1 Effect on Physical & Chemical Properties

When CNT is added as nanoadditive in biodiesel, kinematic viscosity decreases compared to diesel. Also, there is an increase in cetane number and density but a decrease in LHV. Kinematic viscosity and density are lower than diesel fuel when TiO_2 is added as nanoadditive, but cetane number and calorific value are higher when compared. When Al_2O_3 is used as a nanoparticle, Kinematic viscosity, density, flash point, fire point, and cetane number, latent heat increases, but calorific value decreases. Density, kinematic viscosity, flash point, fire point, and calorific value increase, but the cetane index decreases when Bi_2O_3 is added as nanoadditive. When SiO_2 is used as nanoadditive density, kinematic viscosity, flash point, fire point, and cetane index, the calorific value increases, using CeO_2 as nanoadditive decreases kinematic viscosity, density and but increases flash point, fire point and cetane number. Kinematic viscosity and density increase by adding Mn_2O_3 and Co_3O_4 as nanoadditive, but the calorific value decreases. With the use of GO as nanoadditive, there is a decrease in high and low heating values but increases in kinematic viscosity and density. Fe_3O_4 as nanoadditive possess low viscosity, flash point, density, calorific value and cetane number. ZnO as nanoadditive lowers the calorific value, but density and kinematic viscosity are higher. Finally, we have seen that when these nanoadditive are used, we get every property within an allowable limit.

4.2 Combustion Characteristics

The combustion properties of the fuel are changed when biodiesel is blended with nanoadditives, changing the cylinder pressure, HRR, and ignition delay. Different types of nanoadditive increase combustion properties for Cylinder Pressure. The maximum increase is observed in CNT (15-20%) and then in TiO_2 (10-15%), further there is a slight increase in cylinder pressure for the rest of the nanoadditive as for Al_2O_3 (5-7%), ZnO (5-8%), CuO (5-10%), CeO_2 (6-8%) etc. HRR increases with the increase of doping nanoadditive in biodiesel; it is observed that Al_2O_3 and CuO have higher HRR compared to CNT and TiO_2. Others nanoadditive as SiO_2, GO, Bi_2O_3, Mn_2O_3, Fe_3O_4, also increases the HRR. There was a decrement in ignition delay when nanoadditive was used as CNT, TiO_2, SiO_2, Bi_2O_3, GO etc. The lowest ignition delay was observed in CNT.

4.3 Performance Characteristics

It is possible to evaluate the performance of the fuel using EGT, BSFC, and BTE. If a nanoadditive is doped in biofuel, BTE rises while BSFC and EGT fall. Because of high cylinder pressure, CNT and TiO_2 have a lower BSFC than other fuels. Others exhibited a respectable improvement in BSFC; all displayed a 20% average reduction in BSFC, which subsequently declined when the engine load was increased. CNT and TiO_2 are seen to rise in BTE at the highest rates, and BTE also exhibits variations in CeO_2, Al_2O_3, CuO, SiO_2, GO, Bi_2O_3, ZnO, Co_3O_4, Mn_2O_3, and Fe_3O_4. Due to their higher calorific value and heat release than other materials, TiO_2 and CuO have high EGT. The lowest EGT is seen in CNT, and other substances also negatively affect the EGT.

4.4 Emission Characteristics

Unwanted emissions are the end results of burning. Nanoadditives are incorporated into biodiesel to minimise the poisonous fumes that harm living organisms. The most frequent emissions that are seen are CO, CO_2, HC, and NO_X. TiO_2 is employed as a nanoadditive, which significantly reduces CO emissions. Also, CNT shows good results further; it is observed that CO is decreased with doping of nanoadditive TiO_2, CNT, Al_2O_3, Bi_2O_3, CeO_2, SiO_2, CuO, ZnO, GO is the observed order for CO emission. CO_2 emissions are lowest in CNT; there is a reduction in CO_2 emission with the doping of nanoadditive; we observe that CNT, GO, ZnO, CuO, CeO_2, TiO_2, SiO_2, Al_2O_3, Bi_2O_3 is the order for a reduction in CO_2 emission. For HC emission, it is founded that CNT shows the best result. Also, TiO_2 shows a good result. The observed order for HC reduced emission is CNT, TiO_2, Al_2O_3, Bi_2O_3, CeO_2, SiO_2, CuO, GO, ZnO. NO_X emission changes in a different manner. That is, for some nanoadditive it decreases, but for some increases compared to Diesel as CNT reduces the NO_X emission but CuO, TiO_2, SiO_2, Al_2O_3, GO, and Mn_2O_3 increase the NO_X emission.

5 Conclusions

The effects of varying nanoadditives have been investigated, and it is founded that using nanoadditive enhances the properties of biodiesel and reduces EGE. The maximum improvement for cylinder pressure is observed in CNT, the maximum HRR is highest in Al_2O_3, and the lowest ignition delay is observed for CNT. The maximum improvement in BSFC was observed for CNT, maximum BTE was observed in TiO_2, and the lowest EGT was observed with CNT. The lowest CO emission was observed in TiO_2, the lowest HC & CO_2 emission was found with CNT, and the NO_X emission was for CNT. Finally, we have concluded that CNT and TiO_2 showed the best result.

6 Future Scope

More research can be done by taking more nanoadditives in the use of the biodiesel field, and then we can find more alternatives for further research. Also, we will be able to know which nanoadditive is less useful and thus should not be used. That will help researchers, and more ideas will be created.

7 Declarations

7.1 Competing Interests

No conflict of interest exists.

7.2 Acknowledgements

I am immensely pleased to present my paper "Effect of Nanoadditives on Biodiesel Performance and Emission Parameters: A Review". I would like to express my special thanks to my mentor DR. PRASHANT SAINI, who helped me in expanding this field of biodiesel.

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