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A Detailed Review of the Impacts of Diesel/Biofuel Mixes with Nanofluid Additions

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ABSTRACT

Diesel and gasoline will not be able to meet the quick supply of internal combustion engines due to pollution limitations and the accelerating demand for energy in many industries. Because of its availability, acceptance by the environment, and competitiveness, the use of renewable fuel resources to replace fossil diesel fuel in part or totally has become unavoidable. Alternative fuels work well in diesel engines without requiring any adjustments. When compared to utilizing exclusively fossil diesel, alternative fuels can reduce combustion temperature, lowering all emission percentages. Biodiesel is an oxygenated fuel that is one of the alternative fuels used in diesel engine blends. It's critical for lowering brake specific fuel consumption and enhancing brake thermal efficiency. A colloidal mixture of nano-sized particles spread in a liquid media is known as a nanofluid. In a wide range of technical applications, it increases heat transfer qualities and promotes high energy efficiency. Due to their excellent thermo physical qualities, adding nanofluid to diesel/biodiesel as an additive for ICE has been an appealing strategy in recent years, notably in the automobile sector, to promote increased combustion efficiency and emission reduction. The goal of this paper is to compile latest research findings on the impact of nanoparticles on fuel characteristics and engine combustion efficiency. Differing types of additives are also examined and explained when combined with different fuel qualities. Finally, the benefits and possibilities of employing nanofluid as an additional fuel are described in preparation for future study.

KEYWORDS: *Nanoparticles, ICE, Diesel/biodiesel, Fuel properties, Combustion efficiency, Emission control*

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I. INTRODUCTION:

Due to the rising demand for energy in the transportation and power generation sectors for nonrenewable sources of fuels that have been rapidly consumed and the supply cannot keep up with demand, in addition to harmful emissions, manufacturers and researchers are considering renewable resources that meet the need while being environmentally friendly and economically viable [1]. These renewable resources, which are entirely or partially mixed with diesel fuel in diesel engines, are cost-effective, ecologically friendly, and readily accessible [2]. Biofuels, which include bio-alcohols, biodiesel, biogas, vegetable oils, syngas, and solid biofuels, are among the different forms of alternative fuels utilised in diesel engines.

Biodiesel is a monoalkyl ester fuel made from renewable materials such as vegetable or animal fats. Most properties of biodiesel, such as viscosity, flash point, cetane number, and calorific value, are similar to those of regular diesel fuel. Biodiesel may be combined with diesel fuel in any amount without causing the diesel engine to malfunction. Chemical techniques such as pyrolysis, micro emulsion, and transesterification can convert vegetable oils or animal fats to biodiesel.

Bio-alcohols are biofuels that are utilised entirely or partially in diesel engines [3,4]. Bio-alcohols are produced by anaerobic fermentation of biomass wastes [5]. Alcohols contain carbon chains ranging from one to more than twenty. Alcohols have different qualities depending on how many carbon chains they have. Bio-alcohols have drawbacks such as low miscibility with diesel fuel, a high auto ignition temperature, and, unfortunately, are not cost-effective. Diesel-fueled engines are widely employed in the transportation and industrial sectors, owing to their high thermal efficiency and great dependability. The reliance on diesel engines has grown, resulting in increased fossil fuel use. The main producers of greenhouse gas emissions, on the other hand, are prime movers that use traditional fuels like diesel. Substituting renewable fuels like biofuels for fossil fuels can help cut carbon emissions.

Natural gas (NG) is a low-carbon, high-hydrogen (H2) alternative fuel that can reduce CO emissions. Natural gas is derived from carbon-free renewable resources such as biogas. NG can be injected across the intake manifold into a diesel engine to give it enough time to mix with the air before entering the cylinder. Direct injection of diesel fuel. When compared to pure diesel, mixing natural gas with diesel fuel results in lower fuel usage.

Syngas is produced by partial oxidation of biomass, coal, and forest wastes for power generation. Drying, pyrolysis, reduction, and oxidation are the four steps of the gasification process at the gasifier. Syngas contains hydrogen; the primary components are methane and CO, with additional elements such as ammonia and carbon sulphide depending on the gasifier's feeding. Syngas has a low calorific value compared to fossil fuels, produces a high laminar flame, and has a wide range of flammability. When compared to utilising pure diesel alone, deliver minimal fuel usage.

Another addition that has recently been discovered is nano-particle additives, which are utilised to boost the combustion process in diesel engines by enhancing the oxidation process by having a large surface area. When compared to combustion with only diesel fuel, nanoparticle additions enhance mixing, shorten ignition time, boost reaction rate, and minimize emissions [6].

II. NANOFLUIDS

A nanofluid is a new class of heat transfer fluids engineered by dispersing in the base fluid (e.g. water, ethylene glycol and oil) metallic or nonmetallic nanoparticles with a standard size of less than 100 nm, which belong to a new type of functional composite materials developed about a decade ago with the specific aim of increasing the thermal conductivity of heat transfer fluids (Choi, 1995), which have now evolved into a promising Nano technological area. Such thermal nanofluids for heat transfer applications represent a class of its own different from conventional colloids for other applications. Compared to conventional solid-liquid suspensions for heat transfer intensifications, properly engineered thermal nanofluids possess the following advantages:

- High specific surface area and therefore more heat transfer surface between particles and fluids.
- High dispersion stability with predominant Brownian motion of particles.
- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
- Reduced particle clogging as compared to convention slurries, thus promoting system miniaturization.
- Adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations to suit different applications.

Nanoparticles most commonly employed in various studies in different forms such as metals like copper (Cu), silver (Ag) nickel (Ni), and gold (Au); metal oxides like copper oxide (CuO), titanium dioxide (TiO_2), iron(III) oxide (Fe_2O_3), silicon dioxide (SiO_2), zinc oxide (ZnO), iron(II) oxide (Fe_3O_4), zirconium oxide (ZrO_2), and aluminum oxide (Al_2O_3); carbon materials like graphene, carbon nanotubes, and diamond; metal nitrides like Boron nitride (BN), and aluminum nitride (AlN); and metal carbides like silicon carbide (SiC).

2.1. Preparation of Nanofluids

Because of the strong Van der Waals interactions and cohesive forces between nanoparticles, nanofluids can be unstable. Therefore, to break down these forces and create stable nanofluids, the preparation process used in others is extremely necessary. Different techniques, such as pH control, surfactant addition, ultrasonic agitation, magnetic stirring, functionalization and high-pressure homogenization, have been used to prevent nanoparticle agglomeration and increase the stability of nanofluids. There are three key techniques used for the processing of nanofluids: chemical technique in one step, physical technique in one step, and technique in two stages.

The **two-step method** is best used for preparing nano-fluids and is more cost-effective for mass production. The industrial or laboratory-synthesized nanoparticles in these approaches are dispersed by stirring, agitation or ultra-sonication in the base fluids. A major drawback is the lack of stability and a strong trend of agglomeration. Several additional techniques have been used to prevent this challenge, including one-step synthesis techniques and green synthesis techniques.

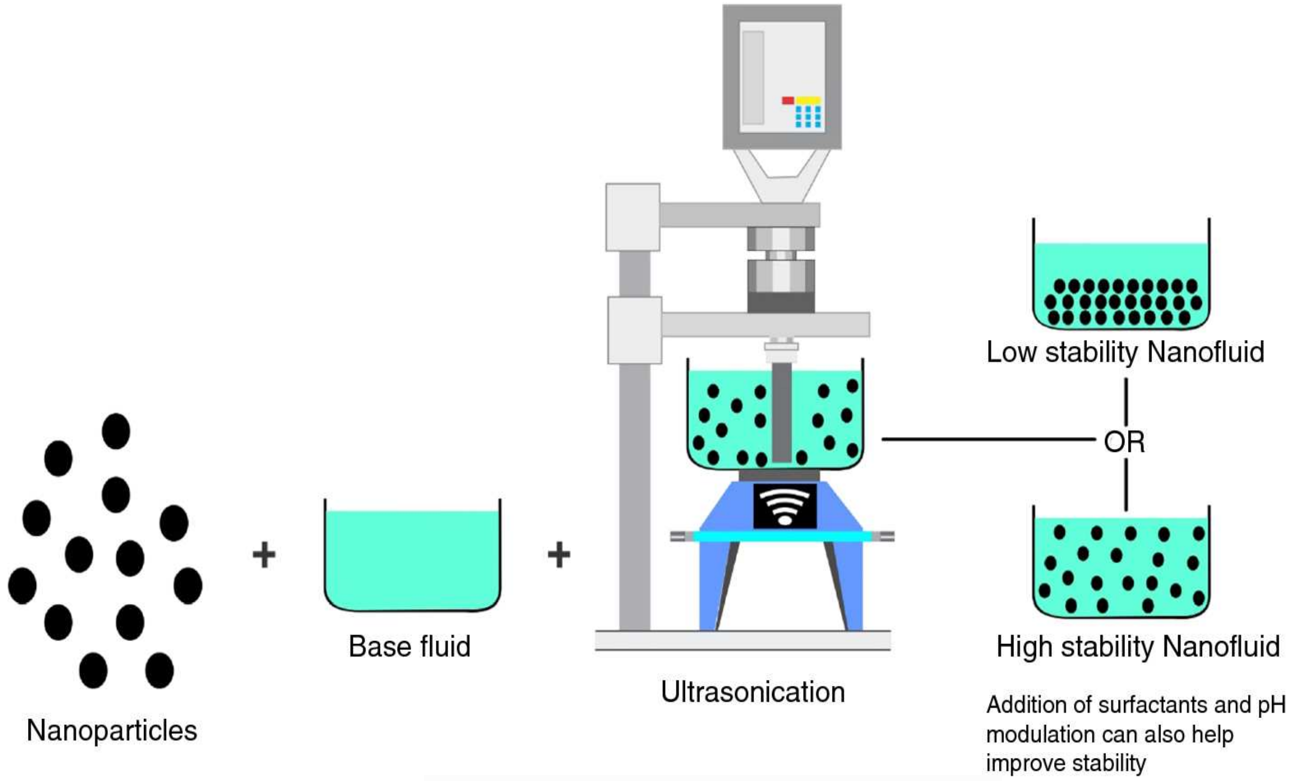

Figure.1. Two-step method of preparing nanofluids.

Both phases, (i) particle formation and (ii) dissemination in the base fluids, occur in the **single-step** process simultaneously. This method removes or prevents all the intermediate processes such as storage, drying, particle dispersion and transportation, thus reducing the nanoparticle accumulation and optimizing the stability of nanofluids.

III. NANOFLUIDS AS DIESEL-BIODIESEL MIX ADDITIVES

Nanotechnologies, such as nanofluids, nanomaterials, and nano composites, have a variety of applications in internal combustion engines [7]. Nano-fluids are fluids containing nano-particles that improve combustion, performance, and emissions. Diesel, biodiesel, or mixed fuels are the basic fluids in compression ignition engines. It has been established that adding nanoparticles to the base fuel increases heat transfer, fuel mixture stability, fuel physical and chemical characteristics, engine performance, and exhaust emissions. In diesel engines, nanoparticles of $FeCl_3$, CeO_2, and MnO may minimise the ignition delay. Because of the rapid evaporation of fuel tiny droplets, the presence of oxygen and water as an emulsion in nano-particles causes micro explosions, boosting combustion.

High heat release, high combustion, high thermal conductivity, and high oxygen content are the major characteristics of these Nano-particles, resulting in a reduction in the BSFC, a reduction in all emissions, and an increase in the BTE. While diesel and biodiesel were combined at (B20-D80) with oxide of nano-graphene at 30, 60, and 90 ppm, study was conducted. The evaporation rate of the mixes rose as engine power increased, and ignition delay reduced [8].

The study used three cerium oxide mixes with tyre pyrolysis oil at 5%, diesel fuel at 90%, and cerium oxide additives at 50 ppm (B5D90 + CeO_2 50 ppm), as well as (B5D85 + CeO_2 100 ppm), (B10D85 + CeO_2 50 ppm), and (B10D80 + CeO_2 100 ppm). All fuel mix properties were shown to be enhanced when compared to gasoline blends lacking Nano-particles [9].

Experiments using Aluminium nanoparticles in diesel fuel on a single cylinder naturally aspirated diesel engine. As Aluminium nanoparticles are added to fuel, the results show a reduction in fuel consumption, smoke, and NOx emissions proportions when compared to diesel at speeds less than 1800rpm in diesel engines [10].

The water–diesel emulsion was combined with alumina nanoparticles as a fuel for a single cylinder naturally aspirated four-stroke air-cooled direct injection diesel engine. Because of the short ignition delay, the heat release rate and peak pressure are lower with nanoparticles combined with water-diesel emulsion than with standard water-diesel emulsion. The use of alumina nanoparticles in a water-diesel emulsion as a fuel considerably improved the diesel engine's brake specific fuel consumption and brake thermal efficiency [11].

IV. EFFECTS OF METAL OXIDE NANOPARTICLES AS ADDITIVES IN DIESEL/BIODIESEL FUEL ON THE PERFORMANCE, COMBUSTION, AND EMISSION CHARACTERISTICS

The main goals of incorporating nanoparticles into diesel/biodiesel fuel are to increase the number of reactive surfaces and enhance the surface-to-volume ratio. It enables the nanoparticles to function as an effective chemical catalyst, improving the fuel-air mixing pattern and fuel combustion performance, resulting in a completely combusted chemical catalyst.

The impact of Nano-particle fuels on combustion parameters such as pressure and heat release, performance characteristics such as braking power, brake thermal efficiency, and BSFC, and emission characteristics such as CO, NOx, UHC, and soot are all thoroughly explored. Brake power, brake specific fuel consumption, and brake thermal efficiency are all affected by the type of nanoparticles used as well as the base fuel. All nanoparticles, in general, lower the BSFC, boosting brake power and thermal efficiency [11].The proportion of reduction or improvement varies depending on the type of nanoparticles used; for example, the BSFC utilizing TiO2 has a reduction of –23.42 percent, whereas GO has a decrease of –23.42 percent.

Until far, researches have confirmed that modest doses of nano additives cannot increase the Nano fuel's lower heating value (LHV) [12]. The key factors that influence combustion are the in-cylinder pressure and the heat release rate. The use of nanofuels enhances the in-cylinder pressure and heat release rate, according to all researchers. For example, by replacing $50CeO_2$ with $100CeO_2$, the in-cylinder pressure was increased by 1.25 percent, as did the heat release [13].

According to most studies, all nanoparticles can lower CO, UHC, and soot emissions. However, because NOx levels can occasionally rise, nanoparticles must be carefully chosen to limit NOx emissions. NOx emissions may be decreased by 70% when Al2O3 is used, 55% when GNP is used, 52% when CNT is used, and 42.7 percent when CeO_2 is used.CO may be decreased by 65.7 percent when CNT is used, 80 percent when Al_2O_3 is used, 65 percent when GNP is used, and 52 percent when CeO_2 is used. UHC may be decreased by 45 percent when $CeO_2$is used, 65 percent when GNP is used, 51 percent when Mn_2O_3 is used, and 44.98 percent when CNT is used. Finally, Al_2O_3, CNT, and CeO may decrease soot by 65 percent, 35 percent, and 30 percent, respectively.

V. CONCLUSIONS

This article presents a current assessment of the impacts of nanofluid as a diesel/biodiesel fuel additive. The use of a nanofluid biodiesel blend in an internal combustion engine (ICE) may be a viable option for lowering GHG emissions and increasing engine efficiency. Nanoparticles have been shown in several studies to improve fuel characteristics, engine performance, fuel combustion, and exhaust emission. One of the most important aspects affecting engine performance and combustion quality is fuel characteristics. The following is a synopsis of this review article.

- In the combustion of diesel engines, mixing nanoparticle additives with fossil diesel fuel alone or with a combination of fossil diesel fuel and alternative fuels can improve the mixture's physical and chemical properties, as well as the engine's performance and emission characteristics.
- Nanoparticles serve a critical function in fostering improved combustion quality. It is possible to increase fuel qualities such as kinematic viscosity, caloric value, flash point, density, and cetane number by adding nanoparticles to diesel/biodiesel, resulting in full combustion. The rise in BTE is attributed to improved fuel characteristics and catalytic activity. A low calorific value, on the other hand, will boost BSFC. In other words, a higher calorific value means a lower BSFC and a larger BTE.
- Increased nanoparticle dosage can improve engine performance and emission characteristics significantly; nevertheless, an excessive quantity of nanoparticles might result in unburned fuel–air mixture during the combustion process.
- Aluminium is the best metal candidate among the aforesaid nanoparticles, whereas CNT is employed for non-metal nanoparticles. This is due to the presence of extra oxygen in nanoparticles, and the favourable impacts of nanoparticles on the fuel characteristics (i.e. greatest calorific value) of diesel/biodiesel blended fuels may boost combustion efficiency, resulting in lower BSFC and hazardous emissions.

The majority of the results are favourable, according to the authors, because adding nanoparticles to diesel/biodiesel can improve the performance of CI engines and minimise hazardous pollutants (HC, CO, smoke, and NOx emissions) that contribute to global air pollution. According to this study of the literature, the majority of the trials undertaken indicated a significant improvement in creating reduced exhaust emissions.

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