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Performance Analysis and Testing of Diesel with Ferric Oxide (Fe_2O_3) Nanomaterial and Pine Oil in Internal Combustion Engine

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Abstract

The goal of the current study is to prepared ferric oxide (Fe_2O_3) nanoparticles, which will be steadily blended with a Pine oil and diesel to enhance the fuel's qualities and the overall characteristics of a variable compression ratio engine called diesel engine. The ferric oxide nano particle pine oil and diesel are the required material for this experiment. Using ultrasonication, the asymmetric (Fe_2O_3) nanoparticles were dissolved in B20 at dose levels 90 ppm nanomaterial. The prepared fuel blend was tested in laboratory of Nepal Oil corporation ltd. Different fuel properties like viscosity, cetane numbers, flash point pour point and density were shown the enhanced results. Also, the calorific value was tested in Centre lab of Tribhuvan university which also shown the improved calorific value than normal fuel. The prepared fuel blends were tested on internal combustion engine i.e. diesel engine at two compression ratio 15 and 16 which shows the better results in IP, BP, ITH, BTH, VE, ME, SFC. The sample 90PPM (Fe_2O_3) in B20 fuel were compared with different compression ratio 15 and 16 which shows the improvement of IP by 9.92%, BP by 4.39%, BTE by 4.64%, ITE by 13.49%, ME by12.83%, VE by 2.89% and SFC by 17.14%.

Keywords

Ferric oxide Nano Particle, Pine Oil, Diesel Engine, Engine Performance

1. Introduction

Humans activities uses fossil fuels in excess all over the world as a non-renewable resource. People are advocating low-carbon living in today's world, and the fossil fuel emissions have negative influence on plants and animals' health as well as on the environment. The change in climate will affect human health over a lifetime, according to the lancet countdown [1] on health and climate change, due to greenhouse effect caused by the huge consumption of fossil fuels, with an average temperatures today greater than four degrees higher than during the pre-industrial revolution period. As a result, there is a pressing need for those fuels that can replace fossil fuels, and exploration for renewable and green alternative fuels that perform similarly has become a hot topic. Internal combustion engine will continue to be the primary source of transportation power in the near future. As a result, the diesel engine should improve its high combustion efficiency while lowering its emissions.

Biodiesel fuels such as jatropha seeds, rapeseed methyl ester and sunflower methyl ester can be blended with the diesel in various ratios to provide superior emission performance and combustion performance, according to extensive study on biodiesel fuels [2] . Furthermore, in tests of diesel-biodiesel fuel blends, researchers discovered various negative impacts, including low pour point, cloud point, poor atomization of fuel injection, lower calorific value, and usually high NOx emissions. As a result, the researchers have experimented with new approaches for the improvement in engine performance and reduce emissions, such as fuel additives and pretreatment blends. Nanoparticles added to diesel-biodiesel have proven to be one of the most successful and promising fuels. It could be because of nanoparticles' numerous superior qualities, like their high energy content, large surface area to the volume ratio, improved number of active centers required for various reactions, processes, high catalytic activity, faster catalytic reaction rate, and so on. The use of fuel blends in diesel engines, produces an acceleration reaction and heterogeneous combustion kinetics that results in a higher energy density [3] . Heat from heterogeneous combustion is convectively transported to the unburned reactants, completing the formation of the end products. Furthermore, a higher surface-to-volume ratio aids in faster oxidation during combustion and a higher combustion enthalpy . High evaporation rate, acceptable flame sustainability, good atomization, and proper mixing of air-fuel are all advantages of nanoparticles, all of which help to lower ID [4]. The early start of combustion process is due to good atomization of fuel.

Metal nanoparticle additives makes improvement in combustion efficiency and efficiency of performance of conventional fuel; though, these additives have some drawbacks, the most serious among them is that exhaust gas of a metal nanoparticle-fueled engine may comprise solid metal oxides as a residual particulate matter, posing significant health related risk, necessitating the use of a filter in the enignine for filtering particulate matter. The possibility of agglomeration, the high cost of supplies, and the difficulties of uniform dispersion are just a few of the disadvantages [5] . There has been some researches on the effects of the fuel blends on diesel engine performance, emissions, and combustion parameters. For example, there have been studies on the effects of fuel blends of TiO2 on improving BTE and lowering brake specific fuel consumption, HC, and CO emissions [6] ; [7] found that employing CeO_2 nanoparticles-diesel fuel blends reduced NOx and HC emissions while marginally increasing carbon monoxide emissions. Furthermore, BSFC was reduced, and no significant differences in brake power were detected in comparison to pure diesel fuel [8]. Ozgur demonstrated that adding nanoparticle additives including MgO, Al_2O_3, TiO_2, SiO_2, ZnO, and Fe_2O_3 to standard diesel fuel for the reduction of NO_x emissions. Ooi et.al. [9] investigated the combustion properties of a CI engine by using aluminum oxide, graphite oxide, and cerium oxide nanoparticles. The use of nanoparticles in diesel engine resulted in a significant increase in the combustion efficiency and reduction in hazardous emissions.

Various experimental experiments on addition of Nano-additives to the diesel blended biodiesel fuel have been undertaken recently, with surprising results. Metals, graphene, metal oxides, carbon nanotubes, organic compounds, and hybrid nanomaterials are main Nano-additives now being studied by researchers. Ferric Oxide (Fe_2O_3) nanoparticles have gained scientific interest among Nano additives according to Zhang [10] . In the compression ignition engine, [11] used a combination of Pongamia oil methyl ester and Fe3O4 nanoparticles (50 ppm, 100 ppm). The results showed noticeably improved BTE, a decreased BSFC, and a significant decrease in UHC, smoke, and CO emissions.

The pine oil blend in diesel played vital role because the SFC and BTE were found to be improved and BP, IP, and BMEP were also observed to be closer to diesel fuel,the diesel blended with pine oil was found to be suitable for the use in compression ignition (CI) engine without making any modification by [12]. They found that the enhanced atomization, fuel vaporization, and burning of less viscous fuels caused the BTE to be slightly greater than diesel fuel. However, due to combined effects of reduced viscosity and increased calorific value, BSFC was somewhat lower than that of diesel fuel. Triglyceride oil (TG oils) and terpene oil (light oil) are the two types of oils that plants often produce. While [13] Demonstrated that terpene oil is derived from plant parts, triglyceride oil is acquired from plant seeds. The impact of compression ratio on the combustion parameters and performance parameters of direct injection CI engines was examined by [14]. Their research showed that when the compression ratio was lowered, the BSFC and there was increment in exhaust gas temperature. But when compression ratio was lowered, BTE fell. Due to their distinct magnetic, electric, optical, and catalytic capabilities, iron oxide nanoparticles have garnered a lot of attention lately[10] . As a result, there are numerous possible applications for iron oxide nanoparticles. Particularly, "functional nanoparticles"—nanoparticles with regulated morphology, size, and composition—have attracted 2 substantial interest in the scientific literature because of their multiple practical uses. A considerable amount of surfactant is not necessary for iron oxide nanoparticles to be soluble and bond with the majority of engine fuels. It is simple to make iron oxide nanoparticles using a chemical process. The nano particle produced from this chemical process is easy and cheap.

2. Materials

Iron(II) oxide (Fe_2O_3) nanoparticles, Pine Oil and Diesel for this work was collected and mixed using ultrasonication technique and tested in an Internal Combustion engine.

3. Preparation of Test Fuel

Test fuels with nanoparticle blends were made using ultrasonication. Ultrasonication is the method of dispersing nanoparticles uniformly in a base fluid by irradiating the base medium with high frequency sound waves. An important component in determining how a nano fuel blend will behave is the uniformity of the distribution of nanoparticles throughout the liquid. When combined with biodiesel blends, nanoparticles have a tendency to cluster and agglomerate, resulting in the creation of sedimented suspension that is readily apparent to an unaided eye. Due to sedimentation's impact on thermo-physical properties like viscosity, density, thermal conductivity, flow behavior, and flow consistencies as a result of the high surface energy of nanoparticles, the performance of final nano fuel blends suffers [15]

As a result, ultrasonication was used to uniformly scatter and stabilize nanoparticles. Stability refers to a nanomaterial's capacity to stay distributed in a base fluid for an extended period of time without forming clusters.

The Sample of Diesel- Pine Oil- and Fe_2O_3 nano material were prepared first as below:

80 % Diesel + 20% Pine Oil + 90PPM Fe_2O_3

4. Comparison of different properties of test fuel

The different properties of the test fuel are characterized and compare it to the diesel fuel. The result obtained from characterization of test fuel is satisfactory and lies on the required range of Fuel

Property	Diesel Value	90 PPM	Method
Kinematic Viscosity @40°C (CSt)	2.0 – 4.5	2.057	ASTM D445
Calorific Value (KJ/kg)	43200	48000	ASTM D2382
Density at 15°C (kg/m^3)	810 – 845	830.7	ASTM D1298
Cetane Number	51-65	55	ASTM D613
Flash Point (Minimum)	35°C	42°C	IP 170
Pour Point °C Max	15	-15	ASTM D97-05

5. Result Validation to the past result

5.1 Indicated Power

The IP of the mixed fuel blends is higher than the pure diesel because of the higher calorific value and lower kinematic viscosity of mixed fuel [16]. According to literature review the indicated power of the IC engine must increase while using the blend of Diesel, Pine oil and Ferric oxide Nano material. The indicated power of the internal combustion engine is gradually increasing when the load is increasing in an engine as shown in figure. In the figure below the IP of 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 9.92%.

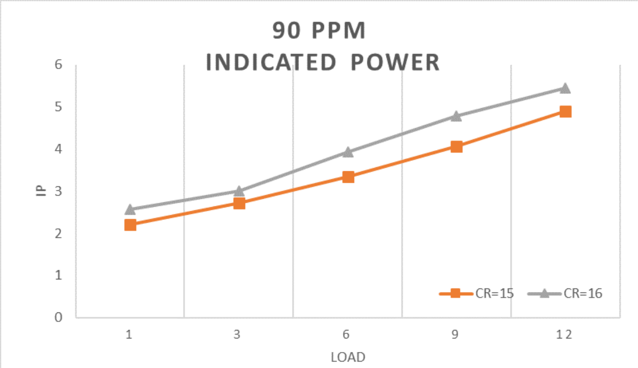

Figure 1: Load vs Indicated Power D+Fe90+ P20 with Different compression ratio 15 and 16

5.2 Brake Power

The BP of the mixed fuel blends is higher than the pure diesel because the lower kinematic viscosity and higher calorific value of the mixed fuel [16]. According to literature review the brake power of the IC engine must increase while using the blend of Diesel, Pine oil and Ferric oxide Nano material. The brake power of the internal combustion engine is gradually increasing when the load is increasing in an engine as shown in figure. In the figure below the BP of 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 4.39%.

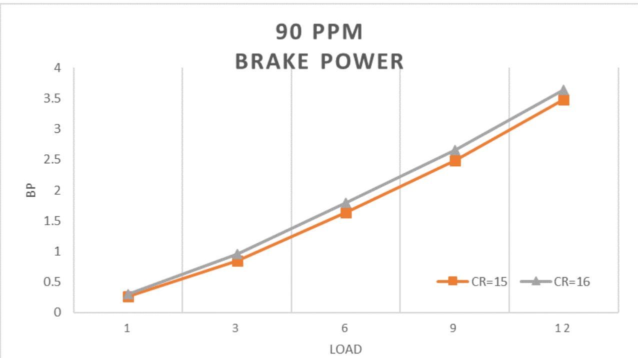

Figure 2: Load vs Brake Power D+Fe90+ P20 at different compression ratio

5.3 Brake Thermal Efficiency and Indicated Thermal Efficiency

At all loading conditions, all test fuels demonstrated an increase in BTHE and ITHE along with an increase in compression ratio, as depicted in Figure [16]. The relationship between BTHE, and engine compression ratio is linear. Greater combustion temperature and pressure are attained at higher compression ratios, increasing the engine's BTHE [17]. ITHE is higher at initial load condition and decreasing linearly while increasing load as shown in figure. In the figure below the BTE of 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 4.64%. ITE of 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 13.49%.

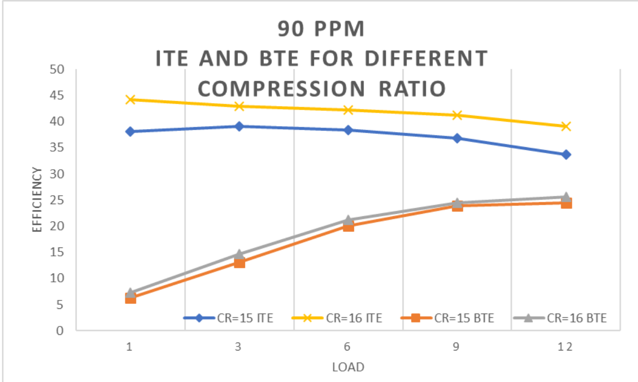

Figure 3: ITE and BTE for different Compression Ratio of D+Fe90+ P20

5.4 Mechanical and volumetric efficiency

The efficiency of internal combustion engines is notoriously low. This is due to the fact that at the crankshaft, the majority of the energy produced by combustion is wasted (dissipated), primarily as a result of heat transfer and friction. Only one third of the combustion energy for a typical engine reaches the crankshaft (at maximum load) (brake output). At part load, where the engine's efficiency is only 20%, the situation is significantly worse. The Mechanical Efficiency of mixed fuel blends is less than the pure diesel [18] because the higher production of heat inside cylinder and losses of heat to the surrounding. Mechanical efficiency of 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is decreased by 12.83%. Volumetric efficiency of 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 2.89%.

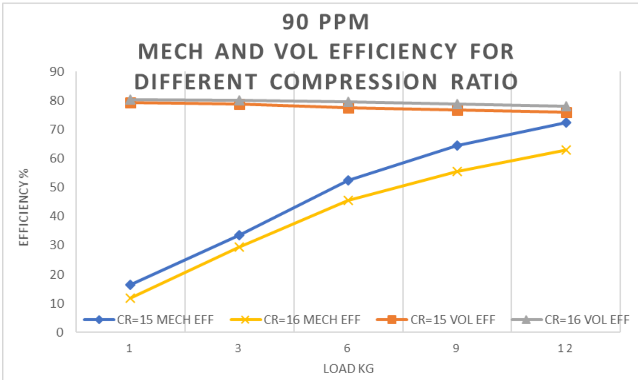

Figure 4: Mechanical and Volumetric Efficiency for different Compression Ratio of D+Fe90+ P20

5.5 Specific Fuel Consumption (SFC)

SFC of a fuel blend including pine oil and ferric oxide nanoparticles lowers as compared to diesel because kinematics of the lower viscosities than that of diesel fuel improved fuel atomization and dispersion in the combustion chamber, which facilitates a quicker and more thorough combustion [16] [17]. SFC declines under higher load circumstances in comparison with diesel. CR and BSFC are inversely related [19]. When the CR is high, more air is forced into the engine, which considerably improves the rate of air-fuel combustion and lowers BSFC. Additionally, at high CR, the mass percentage of unburned fuel is smaller due to the high engine temperature and pressure, resulting in better fuel combustion. In the figure below the SFC of 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is decreased by 17.14%.

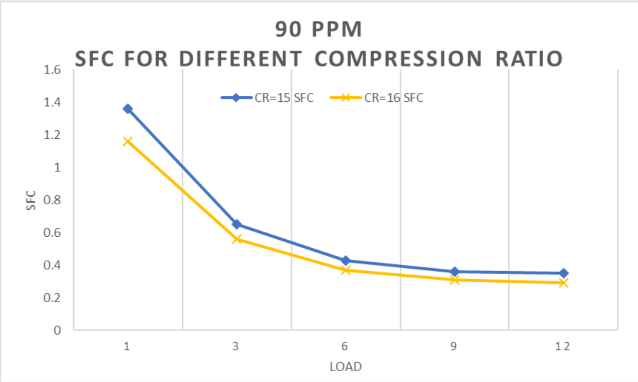

Figure 5: SFC for different Compression Ratio of D+Fe90+ P20

6. Conclusion

The engine was run at two different compression ratios during this investigation: 15 and 16. By using ultrasonication machine with adjusting the dosage levels of 90 ppm of Fe_2O_3 nanoparticles, the fuel blend of B20 90PPM Fe_2O_3 were created.

Grounded on the results, the following conclusions are made:

- Addition of Fe_2O_3 on the base fuel called B20 increases the properties of fuel like calorific value, viscosity, density, cetane number, flash point and pour point.
- The performance characteristics of single cylinder engine was increased significantly by the use of prepared fuel blends.
- The indicated power of the internal combustion engine is gradually increasing when the load is increasing in an engine. IP of Pure diesel and 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 9.92%.
- The BP of Pure diesel and 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 4.39%.
- BTE of Pure diesel and 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 4.64%.
- ITE of Pure diesel and 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is increased by 13.49%.
- The mechanical efficiency of Pure diesel and 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is decreased by 12.83%.
- While the blend of diesel, pine oil and 90 PPM fuel blend at compression ratio 15 and 16 the Volumetric efficiency is increased by 2.89%.
- SFC of Pure diesel and 90 PPM Ferric Oxide Nanomaterial Fuel Blend with Pine oil at compression ratio 15 and 16 is decreased by 17.14%.

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