# A Diesel Engine Performance Investigation Fuelled with Nickel Oxide Nano Fuel-methyl Ester

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**Abstract-** In current paper the Performance investigations were conducted on a Single Cylinder Tangential Vertical-I VCR Engine which was fuelled with blends of palm oil methyl ester and conventional diesel in volumetric proportions of 10%, 20 % and 30% naming B10, B20 and B30. The blends were tested thermo-physically for determing various properties according IS standards. Later Nickel Oxide Nanoparticle is dosed in all the above said mixtures of POME-Diesel in two concentric proportions of 20 and 40ppm in each blend each. The nanoparticle was prepared and various characterization techniques were done to check the preparation and for studying the structural and physical properties of nickel oxide nano particle. The experimental analysis revealed that the fuel dosed with Nanoparticle showed better thermal efficiency of 6.2% and reduction in BSEC and BSFC by 5.119% and 5.6% respectively in comparison to their regular Biodiesel blends.
**Keywords:** Nano Fuels, Nano Particles, Diesel Engine, Biodiesel, Performance

## 1. Introduction

The quench of man’s desire of alternate fuel for current diesel engine and stringent emission norms of internal combustion engine are a challenging task that are brought in deep thought. Biodiesel is one the promising fuel which matches to the current diesel. Meanwhile The Govt. of India is rigorously trying to cut down the import of oil and promote renewable energy. According to the new national policy the Goal of the Ministry of New & Renewable Energy National Policy on Biofuels, India is to ensure that an indicative target of 20% blending of Biofuels, both for bio-diesel and bio-ethanol, by 2017 is proposed [1]. Current days of research on Compression Ignition engine fuelled with biodiesel has taken ages but, its retarded thermal performance, higher NOX emissions and fuel consumption have retarded use of biodiesel. One of the way to control the above drawbacks was by changing the engine operating parameters like compression ratio, Injection pressure and Injection timing[2,4,20].In spite of enormous amount of research by many investigators, there is no exact thought about optimum values of operating parameters that will effect of engine performance and emission characteristics using different biodiesel blends that can be run on engine. Also there is a mist thought of about the permissible amount of biodiesel which can be blended with the conventional diesel fuel so as to attain maximize performance and least emissions from engine [4].

### *1.1 Influence of use of Nano particles in Diesel engine performance*

For these points the additives are blended in fuels for reducing the emissions in certain cases and one such approach adopted is Nano fuels additives to diesel engine fuel, which have constantly reported for better thermal performance and reducing the emissions coming out of diesel engine[5,6]. Nanoparticles have high surface to volume ratio, it promotes combustion by improved atomization. Also the calorific value of the fuel tends to increase as the greater energy density of metal particles, thereby enhancing the performance characteristics of Compression Ignition engine. There are many investigators who have used nano particles or nano fuels doped biodiesel/diesel in diesel engine and have found better combustion phenomenon, and lesser specific fuel consumption using aluminium, iron and boron nanoparticles[7].The use of Nano-metal oxide additives have reported to be effective in lowering diesel emissions [8] like addition of zinc oxide improved the heat release rate, brake thermal efficiency improved and the HC and CO emission dropped[5,9].Biodiesel fuel has meagre oxidation stability which is of major concern for not being used as fuel thereby usage of Nano metal oxides helps in Oxidation and better combustion. Likewise usage of cerium Oxide reduced carbon deposits inside the combustion chamber by burning it off and Oxide particles acts as a donor of oxygen which improved the oxidation process and reduced CO and NOX emittents, thereby decreasing amount of harmful exhaust gas content and significant cleaner combustion [6, 10].Cerium oxide nanoparticles also improve the quality of emission in further reducing the HC emission [11]. Furthermore, Carbon Nanotubes also reduced ignition delay and also priors the peak heat release rate which are features of improvised combustion due to which the harmful emission gasses like CO, NOx and smoke values came down, signifying micro-explosion and improvised atomization phenomena [12,6].Metal oxides like MnO and CuO have also participated in increasing the brake thermal efficiency for regular diesel fuel used in engine. The manganese oxide reduced HC, CO and NOX [8]. Even nanofuels additive like Cobalt Oxide (Co3O4) and Magnalium (Al-Mg) when mixed in Jatropha biodiesel improved the engine's performance and proved enhancement Brake thermal efficiency for magnalium added biodiesel when compared to pure biodiesel. Cobalt oxide nanoparticles doped Jatropha biodiesel showed significant decline in HC emission in comparative to pure biodiesel. In comparison Cobalt Oxide doped Biodiesel proved higher reduction of NOx emission than magnalium doped biodiesel for all load conditions. Aluminum oxide nanoparticles when dosed with biodiesel a showed comparable improvement in Specific Fuel Consumption. The Hydro Carbon and smoke emissions reduced with the addition of aluminium oxide nanoparticles showing a leading outcome on brake thermal efficiency and heat release rate [13].

*1.2 Current Experimental study*

The work was carried out in three stages. In the first stage Nickel Oxide nanoparticles were synthesized using drop wise addition technique and various characterization techniques were used to determine physical significance of formation of Nickel oxide. In the second stage the palm oil was trans-esterified using base catalytic process to form Palm oil methyl ester and blending of Palm oil Methyl ester, Diesel and Nanoparticles were done. In the last stage the properties of the blends were performed using IS standards and performance experimentation of Compression Ignition engine using these blends were determined

## 2. Characterization of Nano particle

FTIR: Fourier Transform Infrared Spectroscopy was brought into service to determine the shape of material and to measure the particle formation. The current Nickel Oxide samples were analysed between the wave numbers 3500cm-1 to 500cm-1. The peaks obtained at 1409.9 cm-1 and 1213.26 cm-1 signify the formation of metal–oxygen (Ni–O) vibrational modes. The results point to the presence of Ni–O bonds.

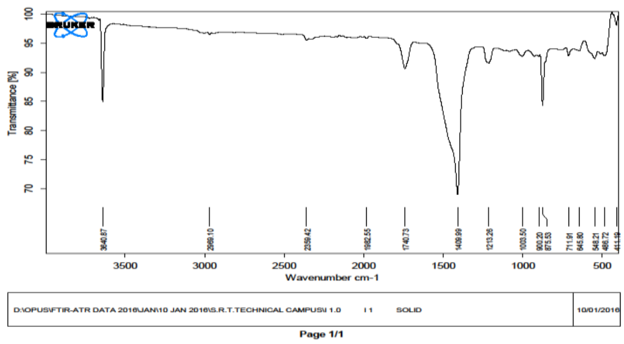


**Fig. 1:** Infrared-scopy of NiO: Wave number to Transmittance

X-Ray powder diffraction:.

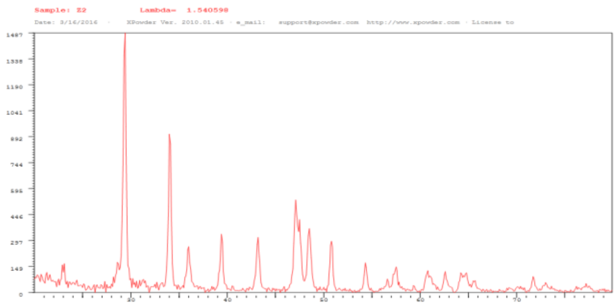

**Fig. 2:** XRD of NiO

XRD is used for finding out phase, orientation, crystallographic structure, and grain size of crystalline material. The above Figure shows XRD pattern of the NiO obtained after diffraction. The X-Ray diffraction was recorded in the range 20o to 80o. Employing Debye Sherrer's formula, particle sizes were calculated from the XRD pattern. The structure of prepared Nickel Chloride is Tetrahedral with a = 2.95 A˚, c =7.27 A˚ and d-spacing is 3.115 A˚. The crystalline size is 13.955. There was a resemblance between experimentally observed spacing data calculated.

FESEM: Field Emission Scanning Electron Microscope is used to visualize very small topographic details on the surface or entire or fractioned objects. In order to study the morphology of the nanostructures the SEM technique is employed. The images were recorded at 4 and 500nano meters. The pictorial view shows clearly the visible crystallite presents in the powder material, which are highly agglomerated. The bright spots exhibit the high crystalline nature of the material in the selected area electron diffraction. The particle size observed from SEM was in range of 7.419nm to 9.539nm

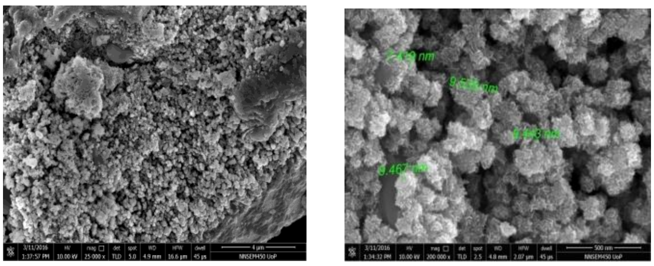

**Fig. 3, 4:** SEM of NiO at 4µm and 500µm

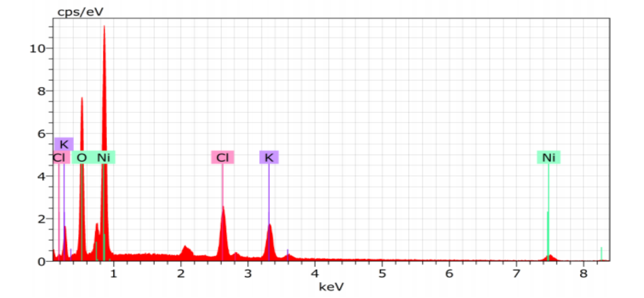


**Fig. 5** EDS: (Energy-dispersive X-ray spectroscopy)

| Parameters | Size |
|---|---|
| Lattice constant (c) | 3.589 |
| % phase | 4.91 |
| Crystalline size | 64.25 |
| Theoretical Density | 14.836nm |
| Axial Ratio (C/A) | 2.25e$^5$ g/cm$^3$ |
| Particle Size | 17.59nm |

Table 1: Characteristics of Nickel Oxide Nano particle

*2.1 Nano Fuel and Fuel Preparation*

Palm oil was heated to remove water traces (if any) present in oil subsequently filtering the heated oil. The oil was employed for base-catalyzed Trans-esterification technique [16]. Later after the biodiesel obtained was further washed with distilled water till whole of the base and glycerol was completely separated. The Trans-Esterified biodiesel were blended with mineral diesel in volumetric proportions B10, B20 and B30.

*2.2.1 Nano fluid preparation*

The nanoparticles usually are immiscible with methyl esters and form sedimentation in the fluid. So In order to diffuse these particles, solvent Iso propyl alcohol was used with a surfactant. For steadiness with the base fluid, Diesterol (surfactant) was used for surface modification which controlled particle sedimentation. For proper dispersion of the nanoparticle with the base, stirring procedure was employed. Weighed quantity of Nickel oxide nanoparticles 20 and 40 ppm was poured in the Iso propyl alcohol solvent and stirred for 1 hr.

*2.2.2 Blending of NiO nanofluid and Palm oil methyl ester.*

Later the above prepared nanofuels containing 20ppm and 40ppm of Nickel Oxide Nanoparticles (NiO) were mixed with Palm oil methyl ester-diesel blend,B10, forming B10 containing 20ppm of NiO particles and B10 containing 40ppm of NiO particles. The above procedure of mixing of Nano fuel was repeated for B20, B30 and B100. So a total of 12 fuel samples were prepared for testing. All these 12 samples were sent for ultrasonification process which improved the stability of the prepared Biodiesel-Diesel-Nano-fuel blends.

Experimental Setup:

The Readings were recorded on a four stroke, naturally aspirated, single cylinder, direct injection diesel engine. The engine was coupled to a water cooled type Eddy current type dynamometer. The Test rig was set to a constant speed of 1500rev/min and the output speed was monitored by a inductive sensor. The fuel consumption rate of engine was recorded with a digital timer and electronic controlled volumetric burette (10cc) which indicates time required. The experiments were conducted at varying torque ratios of 5 N-mt, 10 N-mt, 15 N-mt, 20 N-mt and 25 N-mt. The obtained brake power values are 0.81kW, 1.61kW, 2.40kW, 3.19kW and 3.97kW and Brake mean effective pressure values were 0.28 bar, 0.57 bar, 0.85 bar, 1.14 bar and 1.42 bars respectively for the above mention torque values .The detailed specification of the engine is shown in Table 2

Table no 2: Engine Specifications

| | |
|---|---|
| Engine Make | Comet Engine |
| Rated power | 4.2KW at 1500rpm |
| Loading type | Water cooled, eddy current |
| Load Cell | Strain Gauge |
| Compression Ratio | 17:1 |
| Set Injection timing | 23$^o$bTDC |
| Set Injection Pressure | 210 bar |

**3.Results and Discussion**

Brake Thermal Efficiency (BTHE): From the below figure no.6 the variation of braking torque to obtained brake thermal efficiency can be observed. The BTHE is output parameter which highlights to the fact that obtained thermal energy to output power. Observations wererecorded with a gradual incrementation of braking torque on the engine test rig and the Brake Thermal Efficiency was also found to be increasing in a linear fashion for all blends. As the molecular weight of methyl ester is high and lower calorific value, the palm oil methyl ester were found to combust late in the expansion stroke resulting in lower Brake thermal efficiency for neat biodiesel blends. This was overlooked for Fuels blended with Nickel oxide nanoparticles, as their presence in releasing and storing capacity of oxygen led to increase in thermal efficiency [10].NiO inclusion in the fuel presented secondary atomization and encouraged complete combustion.

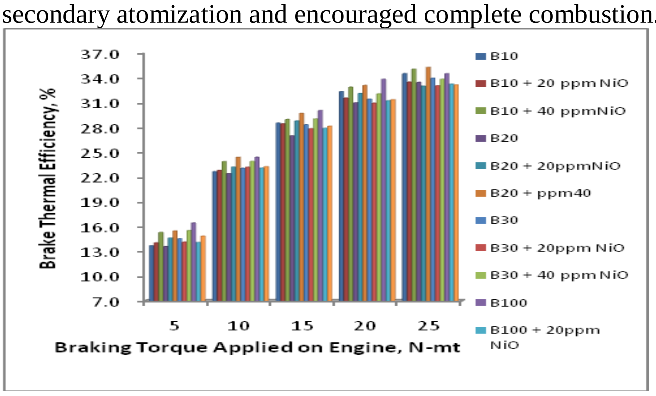


**Fig. 6:** Variation of Brake Thermal efficiency to Torque

Even G. Vairamuthu et al. [14] explored the same effect for Cerium oxide nanoparticles, Also Prabhu L et al. [15] conducted similar study on the effect of titanium oxide nano particle in 20% biodiesel (Neem oil methyl esters) diesel blend on single cylinder diesel engine. B20 blend with 250 ppm dosing level of nano particles exhibited an increment of 1.32% of BTHE at full load conditions.

**Brake Specific Fuel Consumption (BSFC):** It can be comprehended that from figure no 7, that BSFC decreases with arithmetic incrementation of braking torque. As the volumetric concentration of biodiesel in the blend increased, the BSFC also increased which might be due to higher Viscosity and poorer CV (Calorific value) of Methyl ester. Later inculcation of Nickel Oxide nanoparticle blended biodiesel blends tested on CI engine showed improvement. This occurrence might be reduction in physical delay of the combustion of the blend and the nanoparticles formed fuel bearing higher surface area to volume ratio [17].For entire observations of fuel blends tested in CI engine, B20 blend with 40ppm dosing level of NiO nanoparticle proved lowest BSFC. This is due to addition of Nickel oxide nanoparticle which supplied extra oxygen for complete combustion. Similar observations were shown by G. R. kannan et al. [18]who examined use of ferric chloride as a fuel borne catalyst (FBC) for used palm oil based biodiesel with a dosing level of 20imol/L. They remarked that by addition of FBC in biodiesel reduced the brake specific fuel consumption (BSFC) by approximately 8.6%. Even A. Keskin et al.[19]found lowest value of specific fuel consumption for mixtures of 60% tall oil methyl ester and 40% diesel fuel (T60)with cobalt (Co)-based additive for examining engine performance. They noted that Specific fuel consumption values deteriorated marginally with the dosing of Co-based additive.

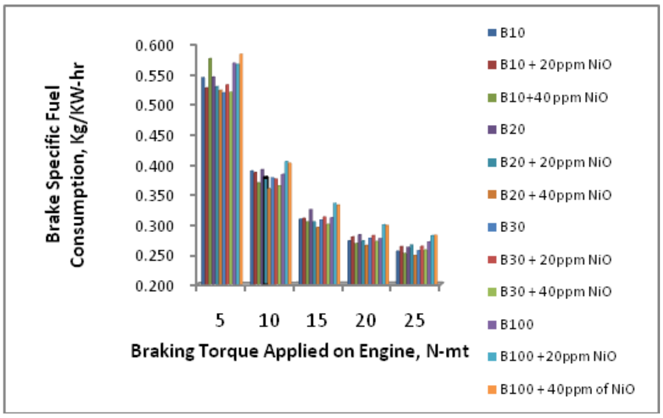


**Fig. 7**: Variation of Brake specific Fuel Consumption to Torque

Brake Specific Energy Consumption (BSEC) The figure no 8 is plotted for knowing the influence of increasing braking torque values to Brake specific energy consumption.For a renewable fuel, BSEC plays avital role as a deciding parameter to analyze the performance as it expenditures the calorific value of blends of fuels. The addition of nanoparticles decremented the BSEC values andfor B20 blend with 40ppm dosing level of NiO nanoparticle was found to be low, which signifies that combustion energy obtained is low.T. Shaafi et al.[3]found minimum BSEC for diesel-soybean biodiesel-ethanol mixtures with alumina particles as additive with a dosing level of 100 mg/lit.

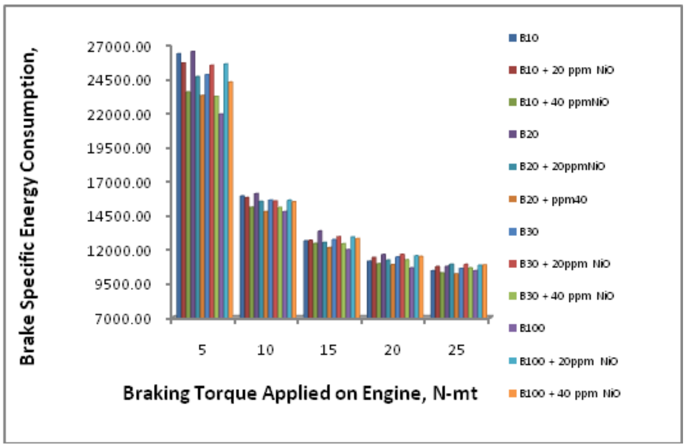


**Fig.8**: Variation of Brake specific energy Consumption to Torque

Heat Supplied

The above graph signifies the variation of Heat Supplied and torque. As we can observe from the graph that as the torque was incremented the Heat Supplied values for all blends increased linearly. Heat supplied is a linear function of heating value of blend. Therefore it is observed that as the volumetric concentration of blending of methyl ester in the blend increases, the heat supplied values reduced. Mixture of fuel and nickel oxide nanoparticles donated additional oxygen which improved complete combustion resulted in burning hydrocarbonsreleasing higher energy[17, 21,22]The purpose of addition of Nanoparticle was to observe heat conduction and which can bring down the engine temperature. So at highest torque value, the heat supplied values for B10, B20 and B30 were 11.91KJ, 11.76 and 11.66 KJ respectively and further addition of nanoparticles with concentration of 20ppm the values rose for B10, B20 and B30 to 11.86, 12.01 and 11.99KJ respectively. With further incrementation od dosing level to 40ppm in same blends the heat supplied values depreciated to 11.29, 11.24 and 11.1KJ.Observing these values the dosing level also effects as the heat supplied as it absorbs some amount of heat energy and moves out with the exhaust gas.

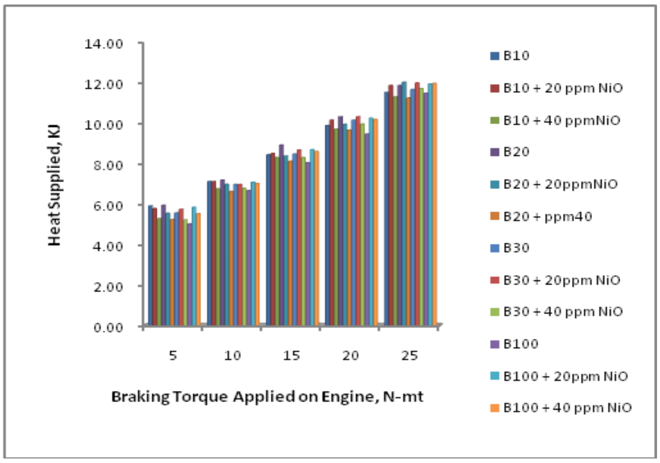


**Fig. 9:** Variation of heat supplied to Torque

## Conclusions

The brake thermal efficiency was seen highest for B20 with NiO 40ppm dosing level. Also Brake thermal efficiency increased with usage of nanoparticles at they provided an energy promoter for secondary atomization and improved the quality of burning. It is observed that the rise in brake thermal efficiency due to nano particles was on average of 6.2% with respect to original base blends (i.e. B10, B20 and B30). The rate of specific fuel consumption was lowest for B20 blend of Diesel-palm oil methyl ester and NiO nanoparticle dosing level of 40ppm. The usage of nanoparticle produced an average reduction of brake specific fuel consumption of 5.6% with respect to their base blends. The addition of nanoparticles decremented the BSEC values andfor B20 blend with 40ppm dosing level of NiO nanoparticle was found to be low. Similarly the usage of nanoparticle depreciated the brake specific energy consumption by 5.119% with respect to their base blends.

From these above observations B20 blend with Nickel Oxide nanofuels with dosing level of 40ppm proved a better alternative to conventional fuel for diesel engine.

*Acronyms*

POME Palm oil methyl ester

ppm Part per Million

DI Direct injection

CI Compression Ignition

VCR Variable compression ratio

B10 10% POME and 90% mineral diesel by volume

B20 20% POME and 80% mineral diesel by volume

B30 30% POME and 70% mineral diesel by volume

BTHE Brake thermal efficiency

BSFC Brake specific fuel consumption

BSEC Brake specific energy consumption

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