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Performance of 4-stroke single cylinder diesel engine using SiO_2 and TiO_2 as Nano additives

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ABSTRACT

An experimental investigation is carried out to establish the performance using silicon dioxide (SiO_2) and Titanium dioxide (TiO_2) as nano-additives in diesel, blended with different proportions per unit liter diesel. These nanoparticles are synthesized by high energy ball milling method and characterized by using characterization techniques such as SEM, EDAX, and XRD. The nanoparticles are blended by means of an ultrasonicator to achieve stable suspension. It is observed that the blends are stable which are suitable for the performance test on the compression ignition engine. The fuel properties of Diesel, Diesel + SiO_2 Nano additive and Diesel + TiO_2 Nano additive in different proportions have been studied and compared according to ASTM standard test methods for biodiesel. The present work mainly focuses on comparing the different nanoparticles in different proportions with diesel to improve the performance of compression ignition engine. The acquired data is studied for various parameters to determine the performance of the CI engine. The result shows a considerable enhancement in performance due to the influence of SiO_2 and TiO_2 nano additive addition in diesel.

Keywords: *Nano additive, ultrasonicator*

1. INTRODUCTION

Nanoscience has taken scientists around the world by storm. It claims to revolutionize the world we live in with radical breakthroughs in areas such as materials and manufacturing, electronics, medicine and healthcare, environment and energy, chemical and pharmaceutical, biotechnology and agriculture, computation and information technology. The transition from microparticles to nanoparticles can lead to a number of changes in physical properties. Two of the major factors in this is the increase in the ratio of surface area to volume, and size of the particle moving into the realm where the quantum effects predominate. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. Particles are further classified according to diameter. Ultrafine particles are the same as nanoparticles and between 1 and 100 Nanometers in size, fine particles are sized between 100 and 2,500 nanometers, and coarse particles cover a range between 2,500 and 10,000 nanometers. Scientific research on nanoparticles is intense as they have many potential applications in medicine, physics, optics, and electronics. The U.S. National Nanotechnology Initiative offers government funding focused on nanoparticle research.

1.1 Classification of Nano-Particles

1.1.1 One-dimension Nanoparticles:

One dimensional system, such as thin film or manufactured surfaces, has been used for decades in electronics, chemistry, and engineering. Production of thin films (sizes1-100 nm) or monolayer is now commonplace in the field of solar cells or catalysis. These thin films are using in different technological applications, including information storage systems, chemical, and biological sensors, fiber-optic systems, magneto-optic and optical device.

1.1.2 Two-dimension Nanoparticles:

Carbon nanotubes (CNTs):

Carbon Nanotubes are a hexagonal network of carbon atoms, 1 nm in diameter and 100 nm in length, as a layer of graphite rolled up into the cylinder. CNTs are of two types, single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs).The small dimensions of carbon nanotubes, combined with their remarkable physical, mechanical and electrical properties, ma take them unique materials (Kohler et al., 2004). They display metallic or semiconductive properties, depending on how the carbon leaf is wound on itself. The current density the that nanotubes can carry is extremely high and can reach one billion amperes per square meter making it a superconductor. The mechanical strength of carbon nanotubes is sixty times greater than the best steels. Carbon nanotubes have a great capacity for molecular absorption and offering a three-dimensional configuration. Moreover, they are chemically and chemically very stable.

1.1.3 Three-dimension Nanoparticles: Fullerenes (Carbon 60):

Fullerenes are spherical cages containing from 28 to more than 100 carbon atoms, contain C. This is a hollow ball composed of interconnected carbon pentagons and hexagons, resembling a soccer ball. Fullerenes are class of materials displaying unique physical properties. They can be subjected to extreme pressure and regain their original shape when the pressure is released. These molecules do not combine with each other, thus giving them the major potential for application as lubricants. They have interesting electrical properties and it has been suggested to use them in the electronic field, ranging from data storage to production of solar cells. Fullerenes are offering potential application in the rich area of nanoelectronics. Since fullerenes are empty structures with dimensions similar to several biologically active molecules, they can be filled with different substances and find the potential medical application.

1.2 Properties of Nanoparticles

1.2.1 Mechanical properties:

Due to the nanometer size, many of the mechanical properties of the nanomaterial re-modified to be different from the bulk materials including the hardness, elastic modulus, fatigue strength, fracture toughness, scratch resistance etc, an enhancement of mechanical properties of nanomaterials can result due to this modification, which are generally resultant from structural perfection of the materials. The elastic constants of nanocrystalline materials have found to be reduced by 30% or less. These results are interpreted because of the large free volume of the interfacial component if resulting from the increased Average interatomic spacing in the boundary regions. Generally, the hardness increases with a decrease in grain size. At very small grain sizes, the hardness decrease with a decrease in grain size. The critical grain size at which this reversal takes place is dependent on one material.

1.2.2Thermal properties:

Many properties of the nanoscale materials have been well studied including the optical, electrical, magnetic and mechanical properties. However, the thermal properties of nanomaterials have only seen slower progress. This is partially due to the difficulties of experimentally measuring and controlling the thermal transport in nanoscale dimensions. Atomic force microscope (AFM) has been used to measure the thermal transport of nanoparticles with nanometre-scale high spatial resolution, providing a promising way to probe the thermal properties with nanostructures. Moreover, the theoretical simulations and analysis of thermal transport in nanostructures are still in infancy. Available approaches including numerical solutions of Fourier's law, a computational calculation based on Boltzmann transport equation and molecular dynamics simulation, all have their limitations. Most importantly as the dimension s go down into the nanoscale, the availability of the definition of temperature is in question. In the non-metallic material system, the thermal energy is mainly carried out in phonons, which gave a wide variation in frequency and the mean free paths. However, the general definition of temperature is based on the average energy of a material system in equilibrium. For macroscopic systems, the dimension is large enough to define a local temperature in each region within the materials and this local temperature will vary from region to region so that one can study the thermal transport properties of the materials based on certain temperature distributions of the materials. But for nanomaterial systems, the dimensions may be too small to define a local temperature.

1.3 Applications of nanoparticles

Nanoparticles offer radical breakthroughs in such areas such as materials and manufacturing, electronics, medical and healthcare, environment and energy, chemical and pharmaceutical, biotechnology and agriculture, computation and information technology and national security. Nanocarbon is used to make rubber tires wear resistant. Nano phosphorous are used for laser coupled devices and cathode ray tubes to display colors. Nano-alumina and silica are used for superfine polishing compounds; Nano iron oxide is used to create the magnetic material used in disc drives and audio/video tapes. Nano zinc oxide or Nano Titania are used in many sunscreens to block harmful UV rays.

1.3.1 Application in Thermal Engineering:

There is a great need for more efficient heat transfer fluids in many industries, from transportation, energy supply to electronics. The coolant, lubricants, oil and other heat transfer fluids used in today's conventional thermal systems have inherently poor heat transfer properties. The conventional working fluids that contain millimeter or micrometer size particles cannot be used in the newly emerging "miniaturized technology "since they clog in microchannels. These problems can be solved with the help of nanotechnology in thermal engineering called nanofluids. The nanofluids have two important factors such as extreme stability and ultra-thermal conductivity.

1.4 Nanoparticles in IC engines

Today the prime mover used for heavy-duty machines are the engines the efficiency of the engine is improved by reducing the fuel consumption rate or effectively utilizing the fuel. This deals with an innovative method to improve the efficiency by reducing the fuel consumption and improving the combustion using the nanoparticles. The various alternative fuels such as biofuels, alcohol-based fuels, Nano fuels etc, made to satisfy the insatiable human need for fossil fuels for ease of transport is well documented and appreciated by its own record.

2. EXPERIMENTAL PROCEDURE

The word synthesis means "The combination of components or elements to form a connected whole."

There are a large number of techniques available to synthesize different types of nanomaterial in the form of colloids, clusters, powders, tubes, rods, wires, thin films, etc. Some of the already existing conventional techniques to synthesize different types of nanomaterials are optimized to get a novel nanomaterial and some new techniques are developed. Nanotechnology is an interdisciplinary subject. Therefore there are various physical, chemical, biological, and hybrid techniques are available to synthesize the nanomaterial. It can be seen for each type there is a large number of possibilities. The list is not complete but gives some commonly used techniques. The technique to be used depends upon the material of interest, type of nanomaterial, viz., zero dimension (0 –D), one dimensional (1D), two dimensional (2-D), their sizes and quantity.

2.1 High Energy Ball Milling

It is a ball milling process where a powder mixture placed in the ball mill is subjected to high energy collision from the balls. This process was developed by Benjamin and his co-workers at the international nickel company in the late of 1960. It was found that this method, termed mechanical alloying, could successfully produce fine, uniform dispersions of oxide particles in nickel-base superalloys that could not be made by more conventional powder metallurgy methods. Their innovation has changed the traditional method in which production of materials is carried out by high-temperature synthesis. Besides material synthesis , high energy ball milling is a way of modifying the conditions in which chemical reactions usually takes place either by changing the reactivity of as milled solids (mechanical activation – increasing reaction rates , lowering reaction temperatures of the ground powders)- or by inducing phase transformations in starting powders whose particles have all the same chemical composition: Amorphization or polymorphic transformations of compounds , disordering of ordered alloys, etc.

2.2 Surfactants

Surfactants or surface active agents are a special class of versatile amphiphilic compounds that possess spatially distinct polar (hydrophilic head) and non – polar (hydrophobic head) group. They show interesting phenomena in solution by modifying the interfacial and bulk solvent properties. The surfactant used to stay stable and not to settle after sonication process for both the silicon dioxide and titanium dioxide is TRITON X-100.

2.3 Preparation of blends

The dosing level of TiO2 and SiO2 nanoparticle samples (by weight) in diesel was varied from 5 to 40 ppm. To obtain a uniform suspension of nanoparticles in diesel, a standard ultrasonic shaker (Power Sonics 405) has been used for mixing the nanoparticles corresponding to the required dosing level. The catalytic nanoparticle added diesel was agitated for about 30 minutes in an ultrasonicator to obtain a stable nanofluid. The modified fuel was used in the experiments immediately after preparation so that considerable time is not allowed for sedimentation to set in.

3. RESULTS

3.1 Diesel

Table 3.1: Performance results for Diesel

S. No	Load switch	BP	BSFC	BMEP	IP	ηbth	ηmech	ηvol	AFR
1.	No load	0	0	0	5	0	0	85.06	80.44
2.	Load 1	1.002	0.424	1.3939	6.002	20.21	16.7	84.68	60.68
3.	Load 2	2.028	0.2485	2.8304	7.028	34.48	28.85	83.93	50.57
4.	Load 3	3.031	0.19	4.2439	8.031	45.10	37.75	83.05	43.625
5.	Load 4	4.058	0.1685	5.7225	9.058	50.85	44.8	83.35	36.63
6.	Full load	5.1059	0.1445	7.2433	10.109	59.33	50.54	82.41	33.38

3.2 Diesel + 0.25gr of SiO_2:

Table 3.2: Performance results for Diesel + 0.25gr of SiO_2 particles

S. No	Load switch	BP	BSFC	BMEP	IP	ηbth	ηmech	ηvol	AFR
1.	No load	0	0	0	5	0	0	85.68	80.46
2.	Load 1	1.002	0.4011	1.4011	6.002	19.67	16.69	84.89	62.69
3.	Load 2	2.028	0.239	2.8242	7.028	35.69	28.61	83.13	47.57
4.	Load 3	3.031	0.188	4.3518	8.031	43.91	38.11	82.91	42.69
5.	Load 4	4.058	0.1596	5.7373	9.058	51.96	44.75	84.65	39.6
6.	Full load	5.1059	0.1237	7.3103	10.109	61.24	50.64	83.62	38.56

3.3 Diesel + 0.5gr of SiO_2:

Table 3.3: Performance Results of Diesel + 0.5gr of SiO_2 particles

S. No	Load switch	BP	BSFC	BMEP	IP	ηbth	ηmech	ηvol	AFR
1.	No load	0	0	0	5	0	0	85.02	78.36
2.	Load 1	1.002	0.401	1.2403	6.002	18.95	15.94	83.96	60.03
3.	Load 2	2.028	0.265	2.3412	7.028	27.65	27.89	83.01	47.09
4.	Load 3	3.031	0.1895	4.019	8.031	42.16	38.001	81.99	41.97
5.	Load 4	4.058	0.1684	5.2587	9.058	49.13	44.24	84.02	37.26
6.	Full load	5.1059	0.1401	7.0159	10.109	58.36	49.98	81.03	37.39

3.4 Diesel + 0.75gr of SiO_2:

Table 3.4: Performance results of Diesel + 0.75gr of SiO_2 particles

S. No	Load switch	BP	BSFC	BMEP	IP	ηbth	ηmech	ηvol	AFR
1.	No load	0	0	0	5	0	0	84.98	78.36
2.	Load 1	1.002	0.3901	1.0056	6.002	18.75	16.01	84.41	59.98
3.	Load 2	2.028	0.257	2.459	7.028	27.56	28.15	82.98	46.38
4.	Load 3	3.031	0.1865	4.085	8.031	42.07	37.65	81.56	42.05
5.	Load 4	4.058	0.1694	5.3745	9.058	48.85	43.98	84.24	38.23
6.	Full load	5.1059	0.1439	7.1987	10.109	58.16	50.21	80.95	37.24

3.5 Diesel + 0.25gr of TiO_2:

Table 3.5: Performance results of Diesel + 0.25gr of TiO_2 particles

S. No	Load switch	BP	BSFC	BMEP	IP	ηbth	ηmech	ηvol	AFR
1.	No load	0	0	0	5	0	0	73.012	64.96
2.	Load 1	1.002	0.3865	1.2928	6.002	16.93	15.68	82.196	51.02
3.	Load 2	2.028	0.2568	2.6285	7.028	27.65	27.56	84.65	42.06
4.	Load 3	3.031	0.1989	4.0156	8.031	39.44	36.56	85.13	41.10
5.	Load 4	4.058	0.2014	5.6984	9.058	50.16	43.21	82.36	25.43
6.	Full load	5.1059	0.1998	7.0153	10.109	59.63	48.36	85.82	23.67

3.6 Diesel + 0.5gr of TiO_2:

Table 3.6: Performance results of Diesel + 0.5gr of TiO_2 particles

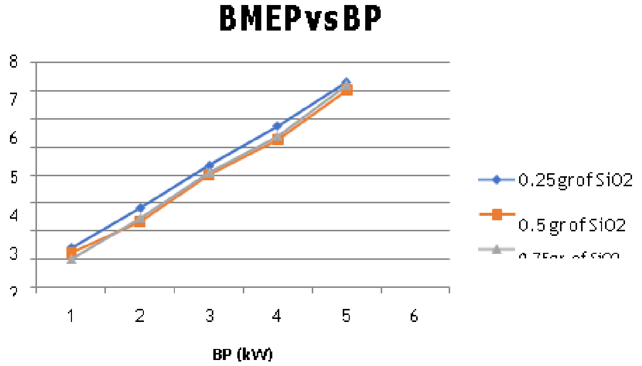
S. No	Load switch	BP	BSFC	BMEP	IP	ηbth	ηmech	ηvol	AFR
1.	No load	0	0	0	5	0	0	74.88	67.45
2.	Load 1	1.002	0.417	1.3975	6.002	21.96	16.69	83.49	51.80
3.	Load 2	2.028	0.236	2.8286	7.028	35.96	28.85	85.65	42.89
4.	Load 3	3.055	0.175	4.2859	8.055	47.38	37.92	86.47	41.26
5.	Load4	4.1066	0.1478	5.852	9.1066	53.96	45.09	83.95	26.69
6.	Full load	5.108	0.119	7.3417	10.108	62.13	50.5	86.73	25.08

3.7 Diesel + 0.75 gr of TiO_2:

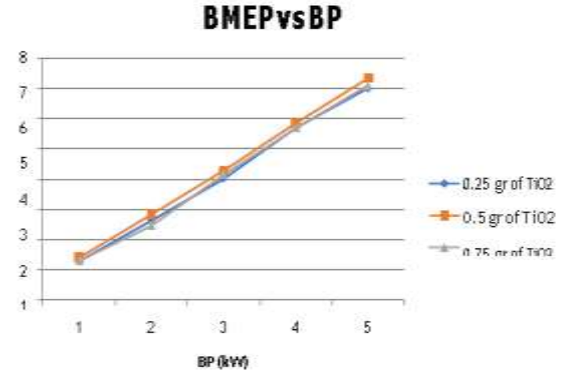
Table 3.7: Performance and results of Diesel + 0.75gr TiO_2 particles

S. No	Load switch	BP	BSFC	BMEP	IP	ηbth	ηmech	ηvol	AFR
1.	No load	0	0	0	5	0	0	73.84	66.54
2.	Load 1	1.002	0.4186	1.3015	6.002	17.015	15.95	83.05	50.86
3.	Load 2	2.028	0.2895	2.8286	7.028	28.3	28.09	85.12	42.19
4.	Load 3	3.031	0.2018	4.2859	8.031	40.98	37.15	85.06	40.08
5.	Load 4	4.058	0.2278	5.852	9.058	50.65	43.68	83.24	25.34
6.	Full load	5.1059	0.1986	7.3417	10.109	61.01	49.94	86.10	23.67

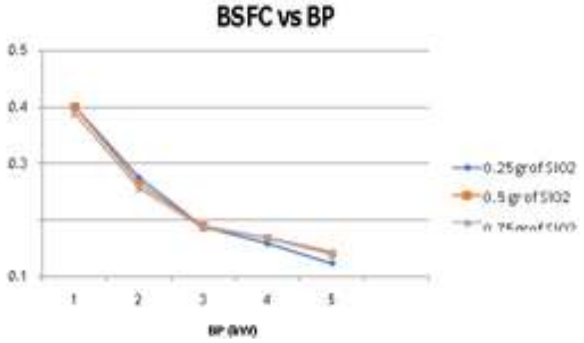
4. GRAPHS



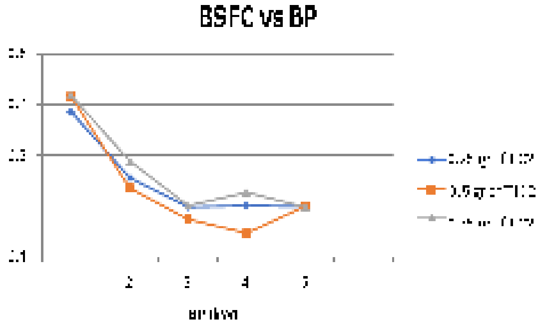
Graph 4.1: Between brake mean effective pressure and brake power for SiO_2 nanoparticles



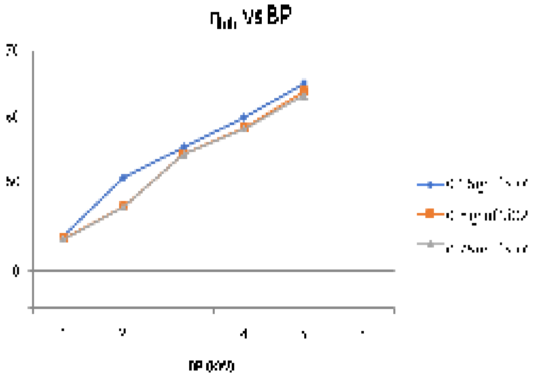
Graph 4.2: Between brake mean effective pressure and brake power for TiO_2 particles



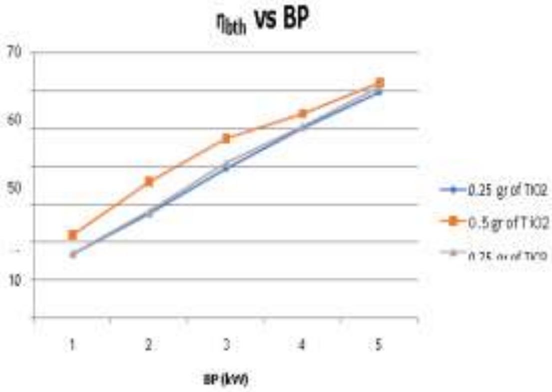
Graph 4.3: Brake specific fuel consumption vs brake power for SiO$_2$ Nanoparticles



Graph 4.4: Between brake specific fuel consumption and brake power for TiO$_2$ nanoparticles



Graph 4.5: Between Brake thermal efficiency and Brake power for SiO$_2$ nanoparticles



Graph 4.6: Between brake thermal efficiency and brake power for TiO$_2$ nanoparticles

5. CONCLUSIONS

- By blending the diesel with nanoparticles, its efficiency increases
- Among 0.25 wt %, 0.5 wt %, 0.75 wt % of Silicon dioxide nanoparticles, 0.25 wt % proportion has less emissions and less fuel consumption.
- Comparing the results at various proportions of Titanium dioxide nanoparticles, at
- 0.5 wt % of the optimized results i.e., lower emissions are observed.
- For SiO$_2$ at 0.25 wt %, 1.91% (full load conditions) efficiency of the fuel increases and fuel consumption of the nano fuel decreased to 2.15% compared to the diesel.
- For TiO$_2$ at 0.5 wt %, 2.8% (at full load) of the efficiency of the fuel increases and fuel consumption decreased to 2.5% compared to the diesel.
- From all the above experiments and according to our results, we concluded that at 0.5 wt % of Titanium dioxide nanoparticles, is observed as the best nano fuel, when it is blended with the diesel.

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