Analysis on Emission Characteristics from A CI Engine using Nano Particles as A Fuel Additives

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Abstract- As we are a part of the 21st century, we are living in a world where luxury has somehow become a necessity for many of us. Mode of working, travelling, living, should be luxurious. In order to full fill one of these luxuries; there is an overall increase in the number of cars being brought. And this has further led to the increase in usage of fossil fuels, which will soon deplete if this continuous. So we need to find an appropriate solution to this problem. Scientific interest in the research of nanoparticles has intensified because of its wide applications in the field of biomedical, optical and electronic, engineering fields. In this review paper we shall take a look at the applications of nanoparticles in CI engines when used as a fuel additive. When the size of a particle lies between 1 to 100 nanometers, the particle is called as a nanoparticle. They are being considered as a discovery of modern science but as a matter of fact they have a long history. Nanoparticles are being used as fuel additives in CI engines and the results that have come are very encouraging and which also gives us an idea of how we make proper use of them in the present and the future to our advantage. And also while performing such experiments a special care was taken to improve the performance parameter such as, power, torque and fuel consumption. Addition of nanoparticles to the fuels also led to a decrease in ignition delay and an appreciable increase in brake thermal efficiency of CI engines. Being a bridge between atomic or molecular structures and bulk materials makes nanoparticles a topic of great scientific interest. Thus a proper analysis of how nanoparticles will work as fuel additives and all its advantages and disadvantages will be given a proper review in this particular paper so that we can utilise them in a proper and efficient manner to give a positive impact to the performance of a CI engine. A number of nanoparticles are made use of as additives in fuels of CI engines. We take a look at the results of some of the applicants that are used.

Keywords: Brake Thermal efficiency, Smoke Opacity, Fuel Consumption, Emission Characteristics

I. INTRODUCTION

Diesel engines can be easily called as the most efficient prime movers today. They are being used more because of their reliability and being economic. Being a more efficient replacement to steam engines, the use of CI engine began. They are being used in submarines and ships since 1910s. Locomotives, trucks, heavy equipment and electricity generating plants later started using such engines. The use of CI engines in automobiles began in the 1930s. The use of diesel engines in larger on-road and off-road vehicles in the USA increased in the 1970s. And this increasing usage of diesel engines led to more use of fossil fuels. And due to the usage of fuels from these many decades we know face a problem of fuel crisis. And due to significant increase in the use of these fuels from the past few decades this problem is going to worsen. If this was not enough we have another problem to add to that and that is the harmful emissions coming out from the engines, these emissions are leading to global warming. Therefore, the use of alternative fuels or effective fuel formulation can be a solution. This will lead to better engine performance and reduce the harmful exhaust emissions. Also a better engine design will help. These things will also result in better brake thermal efficiencies and reduced environmental pollution. One modern lubricant additive which we can make use of are nanoparticles. The reason why we can make use of nanoparticles is because of the several advantages they have over the organic molecules which are currently being used. Due to their nanometer size they can easily enter into the contact area like molecules. They immediately show their efficiency at ambient temperatures also. The preparation of nano lubricants including polymers, metals, organic and inorganic was done with the help of various nanoparticles. The following table gives us the properties of fuel samples with and without nano-additives.

Table 1.1

SR. NO	PARAMETERS	FLASH POINT (ºC)	VISCOSITY (stokes)	CALORIFIC VALUE (kJ/kg)	FIRE POINT (ºC)	DENSITY (gm/cc)
1	**Diesel with nano-particles**	72	3.165	42042	76	0.7002
2	**Diesel**	51	2.981	41794	54	0.6972
3	**% Increase**	41.17	6.17	0.59	40.74	0.43

II NANO PARTICLE ADDITIVES

Fuel formulation with the help of nanoparticle additives takes place to enhance the properties of the fuel to obtain a better output from the diesel. The amount of research that is carried out in this particular area in the past few years is significant. The additives may be ethers, silicon particles, aluminium particles, cerum oxide, titanium particles etc. Such nano-compounds give a positive effect on the diesel fuel lubricity and also help in decreasing the viscosity. Organic compounds of Cu, Ca, Mn, Mg are also used as fuel additives. The extensive use of nanoparticles in fuel formulation also results in improvement of load carrying capacity and reduces the friction and wear of tribo particles. Since the size of the nanoparticles are very small, the overall properties of the material can be improved by manipulating the chemical and physical properties of nanoparticles like (hardness, conductivity, stability, optical sensitivity, melting point, reactivity). Today research is being carried out get information regarding engine characteristics, burning performance and emission parameters of CI engines using nanofuels. Now we show a comparison of various parameters with and without adding nanofuels.

Table 2.1

Sr.No	Parameters	Diesel + Nanoadditive	Diesel
1	POUR POINT (ºC)	-7	6
2	COPPER STRIP CORROSION	1	-
3	CETANE NUMBER	55.4	46
4	CALORIFIC VALUE(MJ/kg)	38.71	42.30
5	KINEMATIC VISCOSITY(40ºC mm^2/sec)	5.98	2

III. ENGINE PERFORMANCE

Power: The force available for the crankshaft is called as power. Watt is the SI unit of power.

Torque: Tendency of a force to rotate about an axis is called torque. Newton-meter is the SI unit of torque.

Brake specific fuel consumption: The rate at which fuel flows to the unit power output is called as brake specific fuel consumption.

Brake thermal efficiency: The ratio of brake power which the engine develops to the heat supplied to the engine is called as brake thermal efficiency.

Tests were carried by using different blends to obtain power. And the results obtained tell us that the produced power was directly proportional to the nanoparticle additives applied and the relation obtained was exactly linear. And when the same tests were carried out to measure the torques, we got the same relation i.e. nanocatylists applied are directly proportional to the increase in torque. The same tests were again used to find out the relation for brake specific fuel consumption and the results obtained were same. Also on the addition of nanoparticles the brake specific fuel consumption decreases. This happens because the required oxygen for combustion is provided by the nanoparticle and thus the combustion is accelerated with the help of nanoparticles and this combined effect is the cause of improvement in the performance of the engine and thereby the brake thermal efficiency increases. The following are observation tables for power obtained and torque obtained with and without nanoadditives.

TABLE 3.1

READINGS	NORMAL TORQUE (N-m)	WITH ADDITIVE TORQUE (N-m)	NORMAL POWER (Watt)	WITH ADDITIVE POWER (Watt)
1	287.6	312.56	883.76	924.56
2	350	387.82	912.66	984.29
3	256.43	280.71	798.34	824.76
4	189.21	231.96	689.99	723.71

A general relation between brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) with and without nano-additives is given by the following table.

TABLE 3.2

READINGS	NORMAL BSFC	WITH ADDITIVE BSFC	NORMAL BTE (%)	WITH ADDITIVE BTE (%)
1	225	205.45	20	35.12
2	278.56	245.31	31.53	43.45
3	326.90	298.78	41.78	53.94
4	378.93	341.89	49.12	62.90

In the above table (table 3.2) the quantity of additives increases with every reading. The values of brake specific fuel consumption and brake thermal efficiency are observed in the above table.

IV. EMISSION CHARACTERISTICS

Emission characteristic give us an idea as to how much exhaust emissions are released by an engine. Weather the gases released are poisonous to the environment or not, if yes then the amount at which it is released so that we get an idea and take efforts to stop it.

There are two types of emissions:

- Emissions produced resulting from lower and from incomplete fuel combustion
- Emissions produced as a result of high temperature of combustion chamber and flame.

As different pollutants form at different different temperatures, simultaneous control of pollutants is difficult. It is clearly noticed that with more concentration of nanoparticles in fuel blends leads to less emission for nitrous oxide and with less concentration of nanoparticles in the fuel blend the nitrous oxide emission is more. The exhaust gas temperature is lowest when blended with nanoparticles. Since there is a presence of nanoparticles in process of combustion, they increase the heat transfer coefficient involved in the products of combustion. Oxides of nitrogen being the major pollutants of air also play a role in the phenomenon of acid rains. The high amount of NO emissions is because of the high combustion temperatures. Thus in such as a way the exhaust emissions of various parameter were analysed.

Table 4.1

SR.NO	PARAMETERS	TEST METHODS
1	NITROGEN OXIDE (PPM)	AVL fuel gas analyzer
2	SMOKE OPACITY	Neptune
3	HYDROCARBON (PPM)	AVL fuel gas analyzer
4	CARBON MONOXIDE (PPM)	AVL fuel gas analyzer

Thus by addition of nanoparticles:

- The NO emissions reduced. This is significantly because of the heat sink effect of the diesel engine.
- The HC emission also reduced. This is due to significant fuel distribution in the presence of nanoparticles and due to intensive secondary atomization.
- The CO emissions were also reduced. The nanoparticles additives lead to accelerated combustion and this lead to shortened ignition delay characteristics and thus the reduced amount of CO emissions.
- The other smoke emissions were also reduced. This was due to improved reactant mixture and reduced soot formation.

V. REVIEW OF SOME RESEARCHERS

5.1 Nithin Samuel et al [1]:-

The use of diesel engines has increased over the past few years. One should also know that the emissions of hydrocarbons, nitrous oxide, etc come from these diesel engines too. Therefore the researchers have studied the application of nanoparticles blended with the fuels as an alternative fuel in the diesel engine. This was done to improve the many of the parameters of the engine. In this particular review we take a look at the experiment performed wherein a pure diesel was first tested individually for all its values and then it was blended with cerum oxide nanoparticles and see the improvement in the performance of the engine. The work was done in two stages, in the first stage the pure diesel was tested in the CI engine and nanoparticles were prepared. In the second stage nanoparticles were blended to the diesel and were tested in 4 stroke CI engine. Cerum oxide is an oxygen donating catalyst or absorbs oxygen for the reduction of NO_2. The oxygen required for oxidation of CO is given by cerum oxide. The carbon deposits are burnt off by the help activation energy provided by cerum oxide inside the cylinder and thus prevents deposition of non polar compounds which leads to reduction in emission of HC. When cerum oxide is added as nanoparticles the emissions of NO_2 and HC were reduced by 30% and 45% and the efficiency of the engine was increased by 5%.

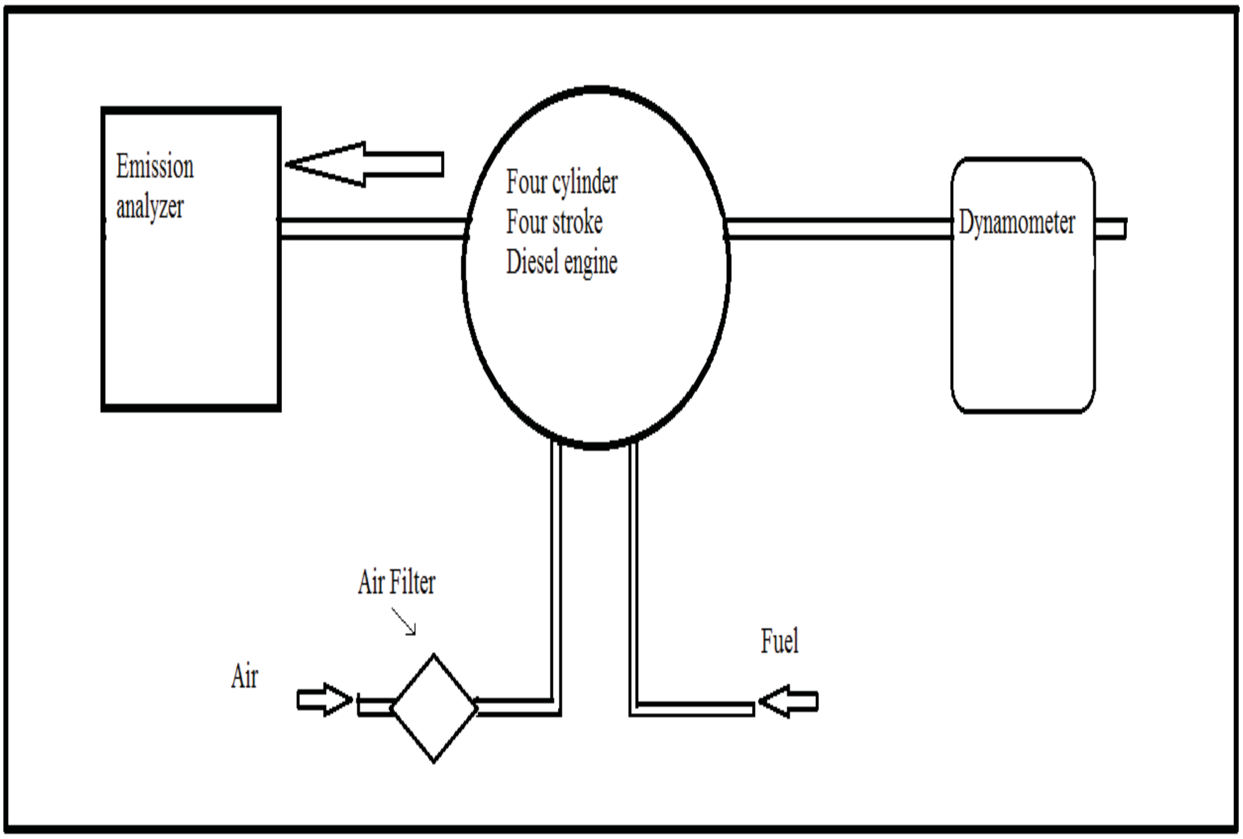
5.1.1 Material specifications

- Four cylinder four stroke engine.
- Nanoparticle added diesel fuel.
- Ultra-sonic shaker.
- A brake drum dynamometer.
- Orsat apparatus

TABLE 5.1: Engine Specifications.

SR.NO	PARAMETERS	VALUES
1	BORE	4 and ½
2	NUMBER OF STROKES	4
3	NUMBER OF CYLINDERS	4
4	TYPE OF COOLING	WATER COOLED
5	BRAKE DRUM RADIUS	0.1 m
6	RATED POWER	15 BHP
7	RATED RPM	1700
8	ROPE THICKNESS	0.8997*10-2 m

5.1.2 Experimental setup



5.1.3 Experimental procedure:

The pure diesel and nanoparticles additive diesel fuel were tested on a four cylinder four stroke engine. Tests on standard constant speed were conducted on the engine. The engine was loaded by a brake drum dynamometer. The ultra-sonic mixer mixes the diesel fuel with cerum oxide nanoparticles. For about 30 minutes in an ultrasonicator the nanoparticles were agitated to obtain a stable nanofluid. The nanoparticle samples were dosed (by wieght) in diesel from 10 to 40 PPM. The exhaust gases from the diesel engine are analysed with the help of an orsat apparatus. It analyses the oxygen, nitrogen, carbon monoxide and carbon dioxide content from the exhaust emissions. The apparatus is usually encased in a wooden box for safety purpose. Potassium hydroxide, cuprous chloride and alkaline pyrogallol were used as absorbents.

TABLE 5.2: Fuel Parameters

SR.NO.	PARAMETERS	DIESEL + CERUM OXID	DIESEL
1	Net calorific value (MJ/kg)	39	43.2
2	Kinematic viscosity (40ºC)	2.35	2
3	Density (15ºC gm/cc)	0.8275	0.83
4	Flash point (ºC)	11	50
5	Fire point (ºC)	14	56
6	Cetane number	44.6	46

5.1.4 Result

This experiment was taken place to observe the effects when cerum oxide nanoparticles were blended with pure diesel. As the fuel is mixed with nanoparticles the specific fuel consumption decreases. Addition of nanoparticles leads to enhancement in fuel combustion and the power output thus needs less amount of fuel. The addition of cerum oxide the mechanical efficiency was also found to be more than other fuels. The thermal efficiency of the diesel mixed with nano particles is less than that of a normal fuel since on addition cerum oxide the calorific value of fuel decreases.

TABLE 5.3: Exhaust Emission Readings

SR.NO	EMISSIONS GASES	DIESEL + CERUM OXIDI (10 PPM)	DIESL + CERUM OXIDE (20 PPM)	DIESEL + CERUM OXIDE (30 PPM)	DIESEL + CERUM OXIDE (40 PPM)	NEAT DIESEL
1	N (%)	83.5	79.3	83	81.6	83
2	CO_2 (%)	10	13	10	11	11
3	O (%)	5	6	6	7	4
4	CO (%)	1.5	1.7	1	1.4	2

5.1.5 Conclusion

Thus we can conclude with the following points:

- On adding cerum oxide in a pure CI engine the amount of exhaust emissions were reduced by a noticeable amount.
- The thermal efficiency of normal fuel is higher than that of additive fuels.
- Fuel added with 30 (PPM) gives us an enhancement of mechanical efficiency by 30% of that of neat diesel.
- Specific fuel consumption reduces by 0.5 kg/kw.hr on addition cerum oxide at 30 PPM.
- The diesel engine performed in a better way when we cerum oxide was added to pure diesel.

5.2 T. Shaafi et al [2]:-

The recent advance in field nanotechnology has helped us to develop many such engines that would give us better performance. This paper was done to study the combustion characteristics, emission and performance of a CI engine when blended with two modified fuel blends that are diesel-soy bean biodiesel-ethanol blends with alumina nano-additives and soya bean biodiesel blend (b20). And the results obtained are compared with that of neat diesel fuel. The properties of both the modified fuels were altered on incorporation of alumina nanoparticles and on soya bean biodiesel addition. For the nano-additive fuel the cylinder pressure and rate at which heat is released is more than that of pure diesel. The temperature of exhaust gas also reduces for the nano-additive fuel. The brake thermal efficiency also decreases during the addition of nanoparticles due to the prevailing temperature difference in the expansion stroke. To achieve stable suspension the nanoparticles were mixed with the fuel blend with the help of an ultrasonicator.

5.2.1 Material specification

- A single cylinder diesel engine.
- The AC generator.
- A rheostat
- An orifice meter.
- K type thermocouple.
- AVL 444 DIGAS analyser.

5.2.2 Result and conclusion

The operation carried was carried out in a very smooth manner.

- The ignition delay rate, rate of heat release and the peak pressure is also higher for the nano-additive fuel as compared to the other fuels.
- The thermal efficiency increases when the nanoparticles of alumina are added.
- There was a reduction in emission of major fuel pollutants like CO, nitrous oxide, etc.

Thus the results that we obtained from the experiments were quite encouraging and give us an idea as to how we take proper steps in the future to improve our engines keeping in mind the environmental aspect.

5.3 J. Sadhik Basha et al [3]:-

The lavish consumption and indiscriminate extraction of fossil fuels has led to reduction in underground sources of fossil fuels. In this particular paper, experiments are done on the properties of a fuel when blended with carbon nanotubes (CNT) and Jatropha Methyl Esters (JME). When Jatropha oil underwent transesterification process JME was produced. And the JME emulsion was in proportions 2% surfactants, 5% water, 93% JME. The JME are blended with in different dosages in the carbon nanotubes. These emulsions were made with a lipophilic-hydrophilic balance of 10. The experimental results showed us a great increase in the brake thermal efficiency of the JME with respect to the pure diesel. And due to the combined effects of secondary atomization and micro-explosion associated with the JME blended CNT, the amount of harmful pollutants in exhaust gases was reduced significantly when compared to that of neat diesel.

5.3.1 Material specification

- Single cylinder four stroke air compressed CI engine.
- AC alternator
- Fuel supply lines, emission analyzers, instrumentation.
- Kistler 6613CA pressure transducer.
- Flame ionization detector.
- AVL DIGAS 444 analyzer.
- Smoke opacity meter.
- JME and CNT emulsion fuel. (25, 50 and 100 PPM).

5.3.2 Results and Conclusion

In addition to the performance, stability characteristics and emission characteristics of the tested fuels were also analysed.

- Owing to the improved combustion characteristics of the fuel when blended with JME and CNT the brake thermal efficiency of fuel was appreciably improved.
- The significant reduction of heat release rate and peak cylinder pressure on the addition of CNT blended JME. Also the ignition delay time was shortened.
- Also the level of harmful pollutants in the air was significantly reduced.

On a general note we can say the CNT blended JME fuels had an improvement in the engine performance and reduction in the harmful exhaust emissions.

5.4Nur Rashid Mat Nuri et al [4]:-

Nanoparticles are being called as an alternate fuel additives or lubricant additives because they have several advantages over organic molecules. In this paper we study the optimal parameters that are statistically significant for getting a low coefficient of friction when pure diesel is blended with alumina and hexagonal boron nitride (hBN). The Taguchi method was used for constructing the design of the material. This method consists of orthogonal arrays. A four ball tester was used for tribological testing according to ASTM standard procedures. The coefficient of friction and wear scar diameter were reduced on the additions of hBN as fuel additive, we obtained this result by having several tests on variance and signal to noise ratio. Several concentrations of 70nm alumina and hBN were used to make the nano-oils. The temperature, load, time and speed were of values 75ºC, 392.4N, 3600 sec and 1200 rpm respectively. Only by adding an appropriate amount of surfactant the samples could be stabilized. In this way we could perform the experiment in a smooth manner.

5.4.1 Material specification

- An ultrasonic homogenizer.
- Concentrations of 70nm alumina and hBN.
- Conventional diesel engine oil.
- Oleic oil used as surfactant.
- A four ball tester.

5.4.2 Results and Conclusion

The addition of alumina has influenced the signal to noise ratio and variance in a great way. But this was a negative impact. The coefficient of friction was increased. However, the addition hBN helped in improving the results. The coefficient of friction was decreased with the addition of hBN. This gave us an idea that fuels when blended with hBN can help in reducing wear of the parts involved in the engine; this would improve the performance of the engine. These additives eventually even had a positive impact on the emissions.

5.5Rolvin D'Silva et al [5]:-

The use of fossil fuels is increasing by the day. Number of vehicles on road is also increasing at a rapid rate. The crisis of fuels is going to increase if this continuous. In this paper the titanium dioxide nanoparticles are made use of as fuel additives in CI engine. Experimentally we first find out the exact concentrations of titanium dioxide to be added. This particular experiment is performed to analyse the parameters like calorific value, density, fire point, viscosity, etc. There was also an increase in brake thermal efficiency by the addition of titanium dioxide. Also there was a reduction in the brake specific fuel consumption on addition of these nanoparticles. As far as emissions are concerned, the emissions of unburnt hydrocarbons and carbon monoxide were reduced. Nowadays metal based additives are also in research. Petroleum diesel was the fuel which was used for investigation. Increased heat release rate and cylinder pressure and decreased ignition delay period were observed.

5.5.1 Material specification

- Computerized single cylinder four stroke engine.
- Titanium dioxide nanoparticles.
- A probe sonicator.
- Fuel tank.
- Fuel measuring unit.
- Manometer.
- Eddy current dynamometer.
- Air box.

- AVL DIGAS 444 analyzer.

5.5.2 Results and Conclusion

It was noted that the value of viscosity, density, fire point, calorific value was increased by adding titanium dioxide nanoparticles. The brake thermal efficiency was improved on account of mixing of titanium dioxide. This was due to better combustion of fuel. The emissions such as oxides of nitrogen increased, whereas CO emissions decreased. The addition of titanium dioxide also improved the overall performance of the engine and thus it can be definitely used as an alternative when required.

The following is a summarized table of all the reviews done above and the conclusions we got.

Sr. No.	Researcher	Nanoparticle Used	Emission Characteristics
1	Nithin Samuel	Cerum Oxide	5% increase in engine efficiency. NO_x and HC emissions decrease 30% and 45% respectively.
2	T. Shaafi	Alumina soya bean blend	Improves the engine performance. Sink temperature reduced. NO_x emissions increased. CO_2 , HC emissions decrease.
3	J. Sadhik Basha	CNT blended with JME	Emission of harmful pollutants Significantly reduced. Brake thermal efficiency increased.
4	Nur Rashid Mat Nuri	Alumina and hBN blend	Scar diameter and coefficient of Friction improved.
5	Rolvin D'Silva	Titanium dioxide (TiO_2)	Emissions of CO reduces by 25% and emissions of unburnt HC reduces by 18%. Bsfc decreases by 22%.

IV. CONCLUSIONS

After reviewing the research papers on this particular topic it can be concluded by saying, research have been done in this field in large amount. The results obtained are also quite encouraging, especially in the times where we could soon face a possible fuel crisis situation. We can use all the positives to our advantage. The emission performance on the addition of nanoparticles is quite good. Some of the chemical parameters of the engines are also improved; we can have an overall improvement in performance of the engine which is what makes this study a successful one. I conclude by saying that the use of nanoparticles as fuel additives in CI engine is safe enough and we can surely rely on it as an alternative fuel.

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