Experimental Study of a Diesel Engine Performance Fueled with Different Types of Nano-Fuel.

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Abstract

The aim of this experimental work is to study the effect of nanoparticles added to diesel fuel on engine performance characteristic. Nano fuels are prepared by adding Al_2O_3 or TiO_2, both with particle size less than 45nm of diesel fuel. Four doses of each type namely (25, 50, 100 and 150) ppm are prepared. These nanoparticles are blended with diesel fuel in varying volume fraction by the means of an electric mixer and an ultrasonicator. The Nano fuels are (DF+Al_2O_3) and (DF+TiO_2). Physicochemical properties of nano fuels are measured and compared with these of neat diesel. The study shows that the addition of nanoparticles to diesel fuel improves its physical properties such as cetane number, thermal conductivity and viscosity. The influence of nanoparticles addition is very clear on the engine performance. The results show that the performance parameters are improved for example, brake thermal efficiency is increased from 19.4% for diesel to 21% and 25% for DF+Al_2O_3 and DF+TiO_2 respectively, the brake specific fuel consumption (BSFC) is decreased by 8% and 20% for DF+Al_2O_3 and DF+TiO_2 respectively, the brake specific energy consumption (BSFC) is decreased by 8% and 20% for DF+Al_2O_3 and DF+TiO_2 respectively at 25ppm and 75% load. The exhaust gas temperature is 382°C for pure diesel while it is 417°C for DF+Al_2O_3 and 353°C for DF+TiO_2. The peak pressure for pure diesel is 62 bar and it increases with DF+Al_2O_3 to 66.2 bar as for DF+TiO_2 the peak pressure decreases to 57.2 bar at full load and 150ppm.

Key words: - Nano fuel, Nanoparticle, Engine performance, Diesel engine.

Nomenclature		**Unit**	**Greek symbols**		**Unit**
C_p	Specific heat	J/kg.ºC	μ	Dynamic viscosity	kg/m.sec
k	Thermal conductivity	W/m ºC	ρ	Density	kg/m^3
m	Mass	kg	φ	Solid volume fraction of nanoparticles	%
			Subscripts		
			f	fuel	-
			nf	Nanofuel	-
			p	Nanoparticle	-

1. Introduction:

The diesel engines are commonly used due to its reliable economy and operation. The increasing use of diesel combustion for powering automobiles has led to considerable increase in environmental pollution such as particulate emissions, carbon monoxide…..etc which causes the problem of global warming. The use of fuel with nano-particles catalyst is, currently, employed to reduce engine exhaust emissions and improve its performance.

[1] investigated the effect of CeO_2 nanoparticles on the performance of compression ignition engine. The test engine was single cylinder, four stroke direct water cooled. The researchers found that CeO_2 nanoparticles (25ppm) act as an oxygen donating catalyst and supply O_2 for the oxidation of carbon monoxide (CO) and reduce NOx. They also reduce UHC and smoke emission and they reduced BSFC to 0.358(kg/kW.hr). [2] investigated experimentally the effect of adding magnetic nanoparticle (10nm) with doses of 0.4 and 0.8 Ferro by volume to the diesel fuel. The tested engine was a 4 stroke, 4 cylinder, 43 kW, water cooled and constant speed (4800 rpm). The results showed that these addition enhanced the performance by increasing the BTE by 12% and decreasing BSFC by 11%. [3] presented an experimental investigation of the effect of adding Al_2O_3 on fuel combustion process. The size of nanoparticles was (10nm). This addition leads to enhancements of the combustion features and a reduction in the formation of carbon monoxide and improvement of combustion stability and efficiency. [4] the test was conducted on a single cylinder, 4stroke and stationary diesel engine. Different doses of CeO_2 nanoparticles (from 5 to 35 ppm) were used. Thermal efficiency was improved by about 6% as compared with that of neat diesel fuel for 35 ppm dose higher loads. Fire point, flash point and viscosity of fuel were increased with the increasing of the dose of nano particles. [5]examined the addition of ZnO nanoparticles effect on the performance of single cylinder, four stroke vertical and cool water diesel engine. The size of the nanoparticles was (1-100) nm with two doses of 250ppm and 500ppm. ZnO additive shortened the ignition delay, The peak pressure increased from 69 bar for diesel fuel to 76.6 and 78 bar for (DF+250ppm ZnO) and (DF+500PPM ZnO) respectively. The brake thermal efficiency was increased from 35.82% for diesel fuel to 36.8% and 37.35% for (DF+250PPMZnO) and (DF+500ppm ZnO) respectively. [6] studied experimentally the effect of addition of cerium oxide to the neat diesel fuel on the performance and emission in a four stroke, cool water, constant speed 1700 rpm and four cylinder compression ignition engine whose rate power is 15HP. The dosages of nanoparticles were 10, 20, 30 and 40ppm. The specific fuel consumption decreased to 0.5(kg/kW.hr) for (DF+30ppmCeO_2). [7] studied the effect of Nano additive on the performance of a CI engine. The tests were performed on a 4 stroke, single cylinder, 5.2 kW and water cooled with constant speed 1500 rpm, diesel engine. The Nano additive were Aluminum (5-150nm), iron (30-60nm) and boron (80-100 nm). It was found that the ignition delay reduced together with BSFC. Brake thermal efficiency increased by 33%. [8] investigated experimentally the effect of Al_2O_3 as an additive to the biodiesel. The test was done on a single cylinder, direct injection (DI) and water cooled engine. They used 25 % of zizipus jujube methyl ester blended fuel (ZJME25). Along with ZJME25 aluminum oxide nanoparticles were added as additive in mass fraction of 25 ppm (AONP25) and 50 ppm (AONP50) was used. Brake specific fuel consumption (BSFC) decreased by 6% when 50ppm (AONP50). Brake thermal efficiency was increased by 2.5% with dosing level of 50ppm (AONP50). Cylinder pressure was increased as 66.115 bar and 69.946 bar for 25ppm (AONP25), 50ppm (AONP50)

respectively. [9] investigated experimentally the effect of alumina oxide Al_2O_3 nano additive on performance and emission of a direct injection diesel engine fueled with methyl ester of neem oil. The alumina oxide nanoparticles were mixed in various proportions from 100 ppm, 200 ppm & 300 ppm with biodiesel. The size of nanoparticles was (1-110 nm). It was found that brake thermal efficiency (BTE) was increased by 2.17%, 4.23 % and 3.49% for (MENO + 100 ppm Al_2O_3), (MENO + 200 ppm Al_2O_3) and (MENO + 300 ppm Al_2O_3) respectively. The addition of nanoparticles reduced the ignition delay priod and reduced heat release rate for all biodiesel blends.

[10] studied theoretically and experimentally the effect of nanoparticles additive on the performance of compression ignition engine. The nanoparticles used were alumina (Al_2O_3) with particle size around 50nm, while density was 3.97g/ml and dosages of 25ppm, 50ppm and 75 ppm. The test was done on a single cylinder, 4stroke cycles, horse power was 7.5 hp, constant speed was1800 rpm, compression ratio was 17.5 and water cooled. It was found that fuel flash point increased from 55°C (diesel) to 62°C (DF+75 ppm Al_2O_3), peak pressure increased from 54 bar (diesel) to 58 bar for (DF+75ppm), brake thermal efficiency increased to 39.6% at full load and dosing level of 75 ppm. The lowest brake specific fuel consumption was 0.224 (kg/kW.hr) for DF+Al_2O_3. [11] studied the emission and consumption in the diesel in C.I engine, direct injection (DI), and water cooled four cylinders, in line and natural aspirated with constant speed (1500 rpm). Nano particles which had been used was cerium and aluminum with different doses. There was a significant improving in the thermal brake efficiency by about 6%. The brake specific fuel consumption reduces to 6%. [12]studied experimentally the influence of addition of titanium oxide (TiO_2) nanoparticle to diesel fuel in a compression ignition engine. The experiments were conducted at constant speed of 1500 rpm and for compression ratio 17.5. The size of nanoparticles was 10-20nm and the dosing level was 80mg/L. They noticed an increase in the brake thermal efficiency by 0.9% at full load when titanium oxide nanoparticles were added. They also found that the addition of titanium oxide diesel fuel reduced the brake specific fuel consumption by 22%. [13] examined the effect of addition of Nano fuel on the performance and emission of diesel engine using stationary, single cylinder, four stroke, constant speed 1500 rpm and water cooled (CI) engine. Aluminum oxide (Al_2O_3) was used as nanoparticles with size between (5-150 nm). They found that BSFC decreased by 7% compared to that of pure diesel. Peak pressure increased at full load for the Nanofuel to about 62. Exhaust gas temperature was increased by 8% and brake thermal efficiency (BTE) by 9% as compared to their counterpartsin pure diesel. The effect of (CeO_2) Cerium Oxide as an additive in diesel fuel, on fuel properties and on engine performance and emission were studied experimentally by [14] investigated experimentally the effect of zinc oxide (ZnO) on performance and emission characteristics of diesel engine. The used dose was 50 ppm and 100 ppm. The tests were done on cool water, constant speed of (1500 rpm) with the fuel injection of pressure (400 bar), varying load, four cylinders, in line and natural aspirated direct injection fait diesel engine. Thermal efficiency was increased and the brake specific fuel consumption decreased with the increase of nanoparticles dose. [15] investigated the effect of (Al_2O_3) aluminum oxide on performance, emission and the characteristic of combustion of a single vertical cylinder diesel engine, 4 stroke, 4.4 kW and constant speed 1500 rpm with 25 ppm and 50ppm blended with diesel fuel. The size of nanoparticles was about 60-70 nm. It was found that using 25 ppm and 50ppm reduced SFC by 7%, 4% respectively. Moreover, the brake thermal efficiency increased by 6% and 3% for 25ppm and 50ppm respectively. Peak cylinder pressure and temperature

were increased by shorting the diffusion combustion of nanoparticle blended fuels. [16] performed an experimental comparative study between the addition of Al_2O_3 and CuO to the neat diesel on the performance and emission of compression ignition engine. Mechanical homogenizer and an ultrasonic devices were used for the purpose of mixing neat diesel fuel with nanoparticle under various mass fraction. They found that Al_2O_3 and CuO reduced the brake specific fuel consumption by 0.5% and 1.2% respectively.

2. Experimental Setup

The experiments were conducted to study the effect of nanoparticles addition on the performance of a single cylinder 4-stroke, water-cooled direct injection diesel engine with a displacement volume of (553 cm^3), variable compression ratio, developing 3.7 kW at 1500 rpm. The engine was fitted with a conventional fuel injection system. The engine has a three holes nozzle of 0.2mm diameter separated at 120 degrees, inclined at an angle of 60 degrees to the cylinder axis. The injector opening pressure recommended by the manufacturer is 120 bar. The complete rig set up is shown in plate (1) and schematically in fig (1). The data acquisition and engine control system is shown in plate (2). The system records the pressure via crank angle diagram (p, ɵ), engine speed (rpm) and temperature of exhaust gases.

3. Fuel and Nano Fuel Preparation

The fuel used in this study is gas oil (diesel) $C_{12.3}H_{22.2,}$ with a density of 844.3 kg/m^3 and a dynamic viscosity of $2.778*10^{-3}$ (kg/m.s). Two types of nanoparticles are chosen, namely Al_2O_3 and TiO_2 with particle size less than 45 nm to be blended with the diesel fuel. The nanoparticles dose was chosen to be 25, 50, 100 and 150 ppm. The mass of nanoparticles required for each dose is calculated using equation (1) below [17] [18].

$$\phi = \frac{\frac{m_p}{\rho_p}}{\frac{m_p}{\rho_p} + \frac{m_f}{\rho_f}} \qquad (1)$$

The physical properties of the nanoparticles and pure diesel fuel used to prepare Nano fuel are shown in table (1).

Table (1) shows the physical properties of nanoparticles and diesel fuel [19].

Substance	Density (kg/m^3)	Dynamic viscosity*10^3 (kg/m.s)	Specific heat(J/kg.K)	Thermal conductivity(W/m.°C)
Al_2O_3	3970	-------	765	40
TiO_2	4230	-------	710	09
Diesel fuel	844.3	2.778	----	-------

Table (2) shows the mass of nanoparticles required for each dose for both types as calculated by equation (1).

Table (2) mass of nano-particles (for five liters of fuel).

Volume ratio (ppm)	ϕ%	Mass of particles (m_p) (g) (Al_2O_3)	Mass of particles (m_p) (g) (TiO_2)
25	0.0025	0.4963	0.529
50	0.005	0.993	1.058
100	0.01	1.986	2.116
150	0.015	2.979	3.174

The measured quantity of nanoparticles is added to five litter (5 L) of diesel fuel and mixed continuously for one hour by a mixer, see plate (3), to ensure the spreading of nanoparticles within the diesel fuel to prevent aggregation of particles quickly. An ultrasonic cleaner type (JTS-1018), see plate (4), is used to complete the mixing process. The mixing process continues for another six hours.

4. Results and Discussion.

4.1 Fuel Consumption:

Figures (1and 2) show the effect of nanoparticles blending on fuel consumption at full load for different speeds. It is shown that fuel consumption of pure diesel increases with speed due to increase of fraction. The figures below show that the 25ppm nanoparticles dose give minimum fuel consumption for all speeds and with both types of nanoparticles. However, the effect of TiO_2 is more significant. The increase of nanoparticle dose beyond 25ppm increases fuel consumption but it is still less than that for the pure diesel. It is thought that the nanoparticles act as oxygen buffer to improve combustion process and release as maximum as possible of heat [17].

4.2 Equivalence ratio:

Figures(3and 4) show that the equivalence ratio (φ) reached its minimum value with 25ppm for both types of nanoparticle and increased with the further increase in dose level. The reeducation in φ with Al_2O_3 and TiO_2 is 7% and 22.5% respectively. This reduction is due to the lower fuel consumption which means efficient combustion process caused by the improved fuel properties.

4.3 Volumetric Efficiency: η_V

Figures (5and 6) show that the addition of Al_2O_3 and TiO_2 to diesel fuel produces a contradicting effect on volumetric efficiency where Al_2O_3 reduces it slightly, while TiO_2 increases it slightly. This can be related to higher cylinder pressure and temperature caused by the addition of Al_2O_3 as it will be clarified later in this paper.

4.4 Brake Thermal Efficiency:

The effect of nanoparticles addition to diesel fuel on brake thermal efficiency is shown in figures (7and 8) for different loads. It is noticed that the addition of both types of nanoparticles improves the brake thermal efficiency but the maximum improvement is noticed at 25ppm dose. However the effect of TiO_2 is higher than that of Al_2O_3. The maximum brake thermal efficiency obtained is 21% for Al_2O_3 and 24.9% for TiO_2. This improvement in brake thermal efficiency is contributed to the better combustion process caused by the presence of nanoparticles. The BTE is increased by 8.2% and 28.44% for Al_2O_3 and TiO_2 respectively at 75% load and 25ppm.

4.5 Brake specific fuel consumption (BSFC):

Figures (9and10) show the variation of brake specific fuel consumption (BSFC) with dose levels of both types of nanoparticles. The result shows that the brake specific fuel consumption reduces with the addition of nanoparticles. However, the maximum reduction obtained is with 25ppm dose which is 8% and 20% for Al_2O_3 and TiO_2 respectively. It is thought that the nanoparticles act as an oxygen buffer which improves the combustion process and enhances the heat release.

4.6 Brake specific Energy consumption (BSEC):

Figures (11and 12) show the variation of brake specific energy consumption (BSEC) with dose level of nanoparticles. The BSEC reduces with both types of nanoparticles, but the reduction is more with TiO_2. DF+25ppm Al_2O_3 shows a decrease of about 7%, but DF+25ppmTiO_2 shows around 20% reduction. This is due to improvement of fuel properties caused by the presence of nanoparticles which improves combustion process. It is also thought that nanoparticles act as an oxygen buffer which improves combustion process and leads to a less fuel consumption.

4.7 Exhaust Gas Temperature:

Figures (13and 14) show the effect of nanoparticles addition on exhausted gas temperature at different loads and different doses. It is shown that TiO_2 nanoparticles reduce T_{exh} and this effects increases as the dose increases. This is due to the relatively shorter delay period and lesser maximum cylinder pressure as it will be explained later. However, the addition of Al_2O_3 increases T_{exh} for all loads. This increase may be due to the higher maximum cylinder pressure caused by the pressure of Al_2O_3 nanoparticles.

4.8 Cylinder Pressure:

Figures (15, 16and 17) show the cylinder pressure history diagram for pure diesel, DF+25ppm Al_2O_3 and DF+25ppm TiO_2. The comparison shows that Al_2O_3 nanoparticles increases the maximum cylinder while the TiO_2 reduces the maximum cylinder pressure as compared to that of the pure diesel. The effect of TiO_2 may be due to the shorter delay period and hence the less premixed fraction of combustion process. For example at 25% load the maximum pressure is reduced from 57 bar for pure diesel to 56.5 bar for DF+25 ppm TiO_2. The adverse effect occurs with the addition of Al_2O_3 nanoparticles where the maximum cylinder pressure is increased to 57.5bar since Al_2O_3 has a little effect on delay period though it improves combustions process. As the maximum cylinder pressure timing moves closer to TDC the effective expansion process becomes longer and more power is produced and hence better brake thermal efficiency is gotten. Figures (18, 19, 20, 21, 22 and 23) show the cylinder pressure history for 50ppm, 100ppm and 150ppm of Al_2O_3 and TiO_2 at 25% load. The same trends are noticed in figures (16and 17). As the maximum cylinder pressure timing moves closer to TDC the effective expansion process becomes longer and more power is produced and hence better brake thermal efficiency is obtained. Figures (24and25) show the variation of maximum pressure with nanoparticles dose. The maximum pressure is increased with the addition of Al_2O_3. This increase is due to the high pressure in the small volume then the cylinder pressure increases, so the increasing in peak pressure means an advance toward the TDC. The reduction in peak pressure means delay of TDC. Figures (26and 27) show the timing of maximum pressure with the dose level of nanoparticles. It is clear that the P_{max} with Al_2O_3 approaches the TDC more than it does with the TiO_2. Also figs (26 and 27) show the advancing with Al_2O_3 and delaying with TiO_2. Figs (28 and 29) show the variation of the differences in maximum pressure with nanoparticles dose. The maximum pressure with Al_2O_3 approaches ATDC, while P_{max} with TiO_2 is a bit faraway from ATDC.

5. Conclusions

1. The equivalence ratio (φ) decreases by 25ppm for both types of nanoparticles, but the effect of TiO_2 is more than that of Al_2O_3.
2. The brake thermal efficiency with TiO_2 (25ppm) is better than that with Al_2O_3 (25ppm). The maximum BTE for Al_2O_3 is (21%) and for TiO_2 it is (24.94%), at 25ppm.
3. The maximum reduction in BSFC is obtained at a dose of 25ppm which is 8% and 20% for Al_2O_3 and TiO_2 respectively, while the reduction in BSEC is 7% and 20% for Al_2O_3(25ppm) and TiO_2(25ppm) respectively.
4. The exhausted gas temperature decreases with the increase of TiO_2 the dosage, but it increases with the increase of $Al_2O_3$the dosage.
5. The peak pressure decreases with TiO_2 as compared to that of the pure diesel i.e (from 62.034 bar to 57.18 bar), while it increases with Al_2O_3 nanoparticles.
6. The timing of maximum pressure moves closer to TDC with Al_2O_3 nanoparticles addition than it does with TiO_2.

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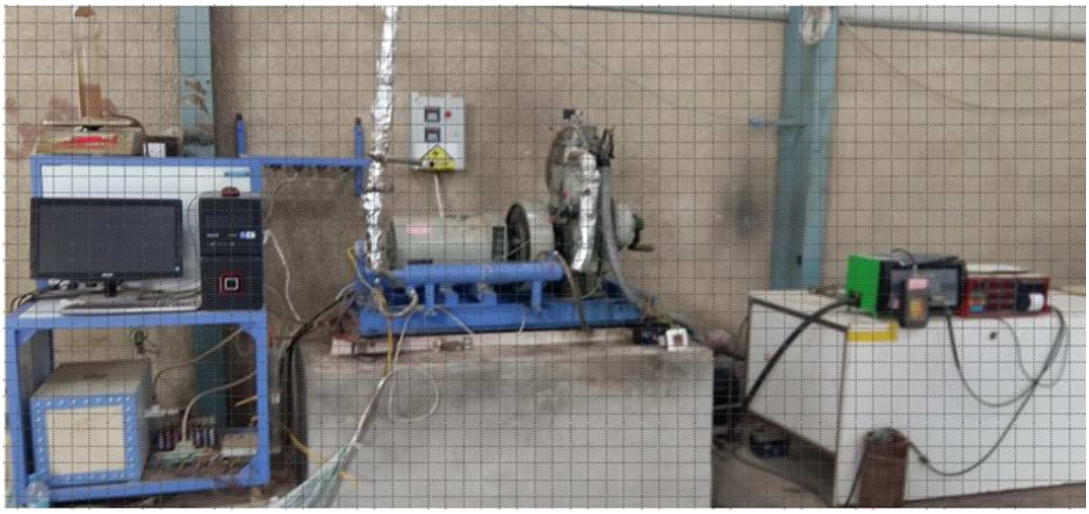
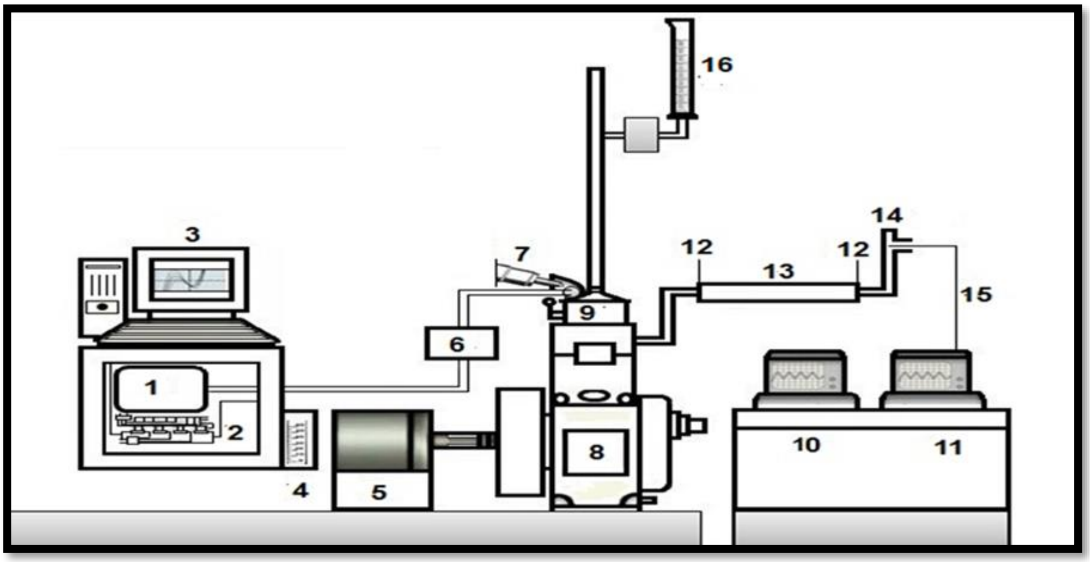


Plate (1) Front View of the Experimental Set Up



1	Air surge tank	7	Fuel injector	13	Calorimeter
2	Data Logger	8	Engine block	14	Silencer tip
3	PC	9	Cylinder head	15	Exhaust gas probe
4	Water manometer	10	Gas analyzer	16	Fuel tank
5	Eddy current	11	Smoke meter		
6	Intake air	12	PT-100 sensor		

Fig (1) Schematic Diagram of Experimental Set Up

Plate (2) Data Acquisition System

Plate (3) Photograph of a Mixer

Plate (4): A Photograph of an Ultrasonic Cleaner

Table (3) Specifications of Ultrasonic Cleaner Bath

Model	JTS-1018
Tanks working dimension (mm)	L_1= 406 , W_1=305, H_1=460
Overall dimension (mm)	L_1= 586 , W_1=485, H_1=680
Ultrasonic frequency	40 kHz
Ultrasonic power	720 Watt (variable)
Digital timer control	1-30 min
Capacity	54 liter
Temperature control range (°C)	< 90 °C
Ultrasonic power output	800 W

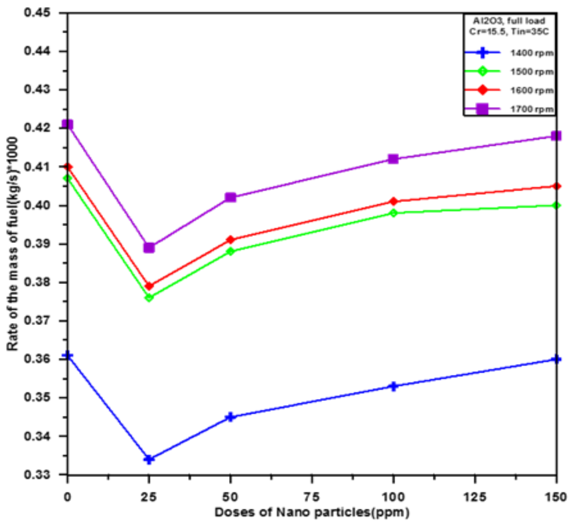


Fig 1: Variation of rate of fuel consumption with nanoparticles dose.

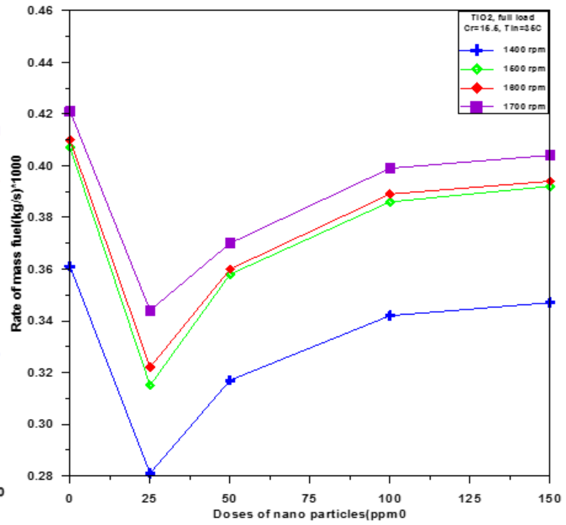


Fig 2: Variation of rate of fuel consumption with nanoparticles dose.

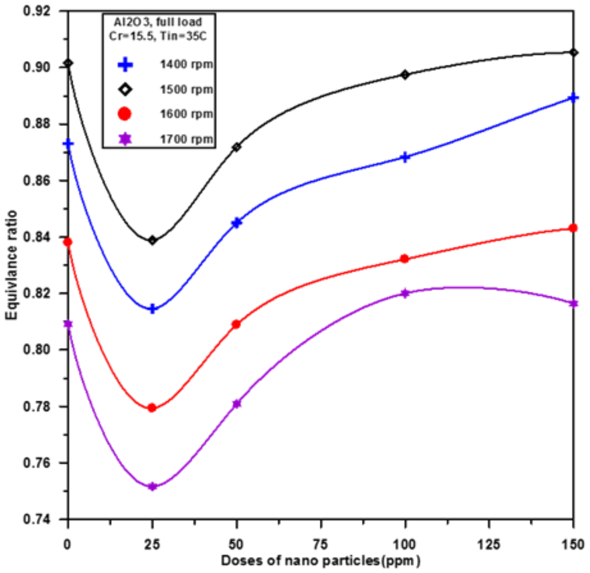


Fig 3: Variation of equivalence ratio with nanoparticles dose.

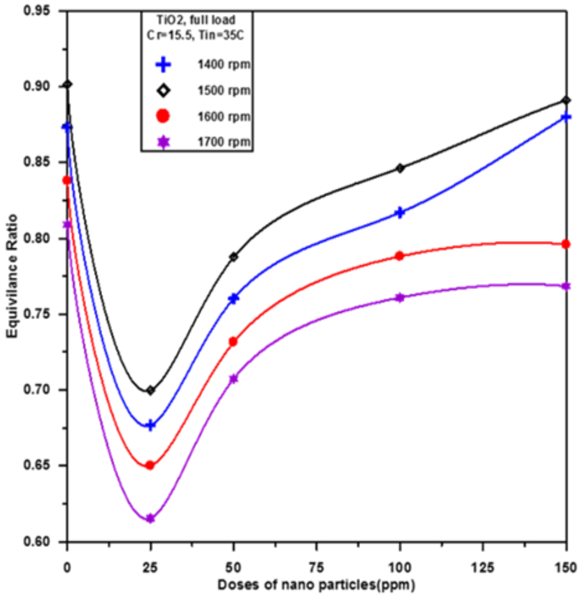


Fig 4: Variation of equivalence ratio with nanoparticles dose.

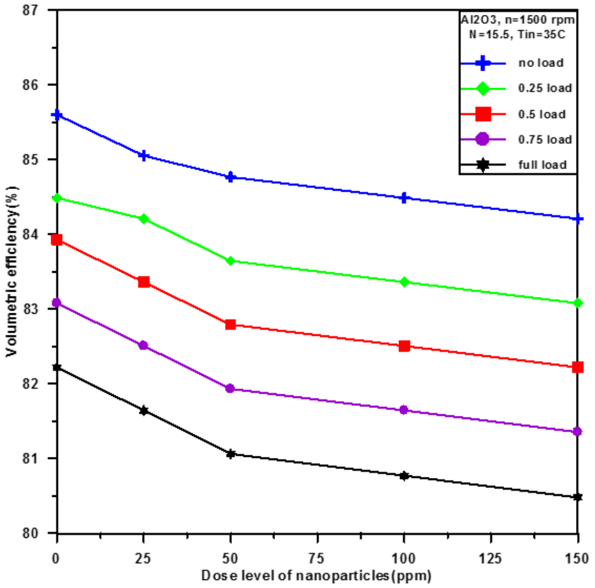


Fig 5: Variation of volumetric efficiency with nanoparticles dose.

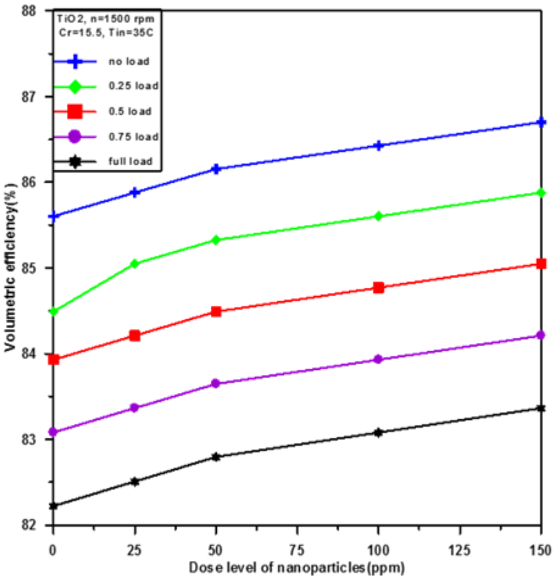


Fig 6: Variation of volumetric efficiency with nanoparticles dose.

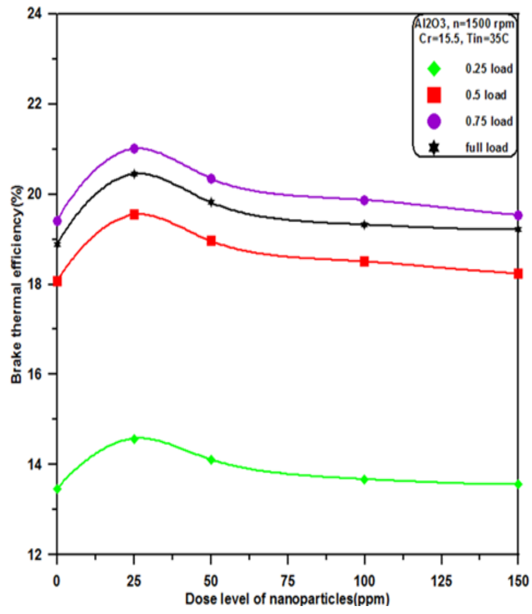


Fig 7: Variation of brake thermal efficiency with nanoparticles dose.

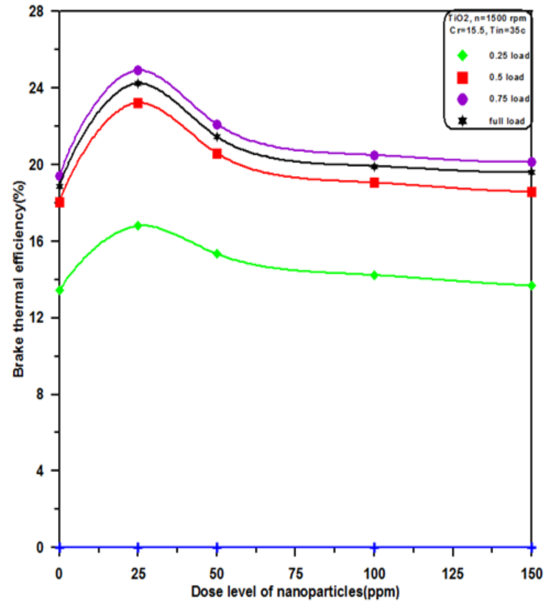


Fig 8: Variation of brake thermal efficiency with nanoparticles dose.

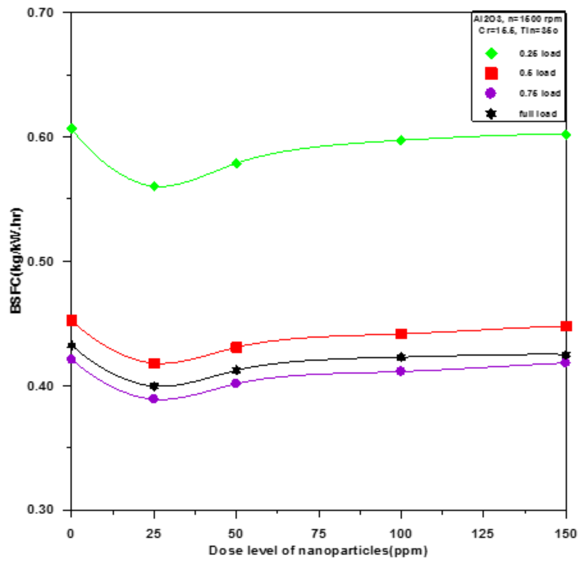


Fig 9: Variation of brake specific fuel consumption with nanoparticles dose.

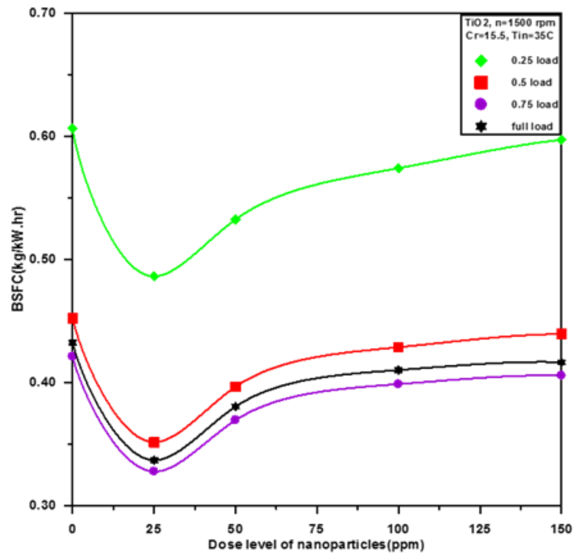


Fig 10: Variation of brake specific fuel consumption with nanoparticles dose.

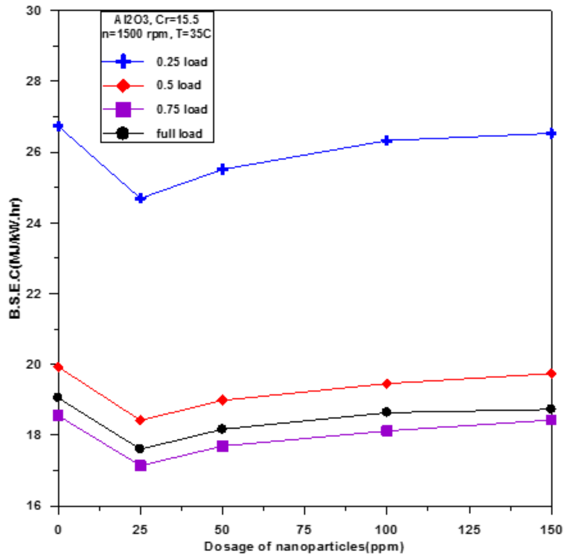


Fig 11: Variation of brake specific energy consumption with nanoparticles

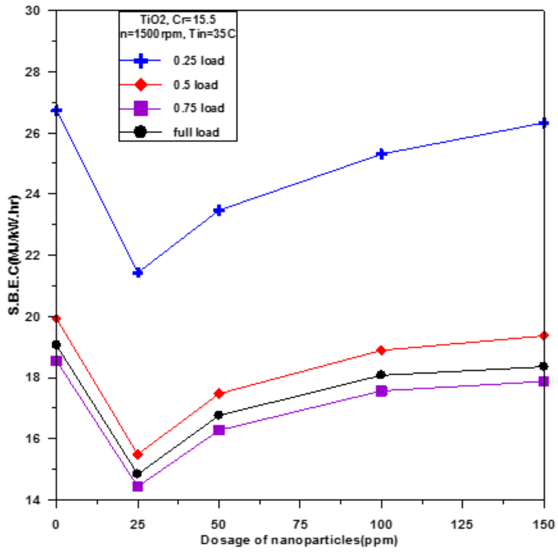


Fig 12: Variation of brake specific energy consumption with nanoparticles

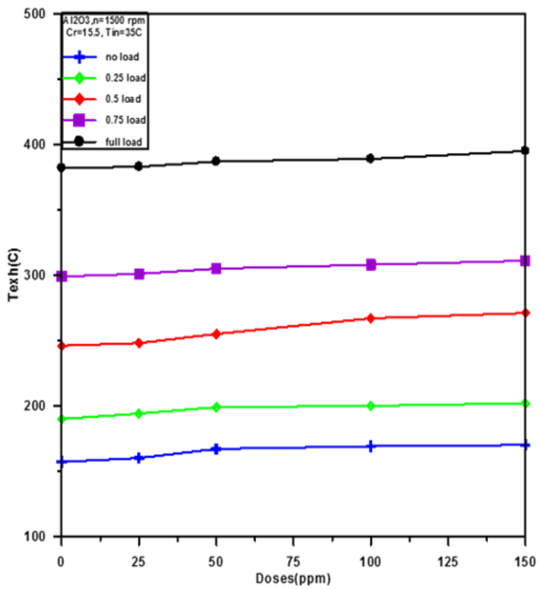


Fig 13: Variation of the exhaust temperature with nanoparticles dose.

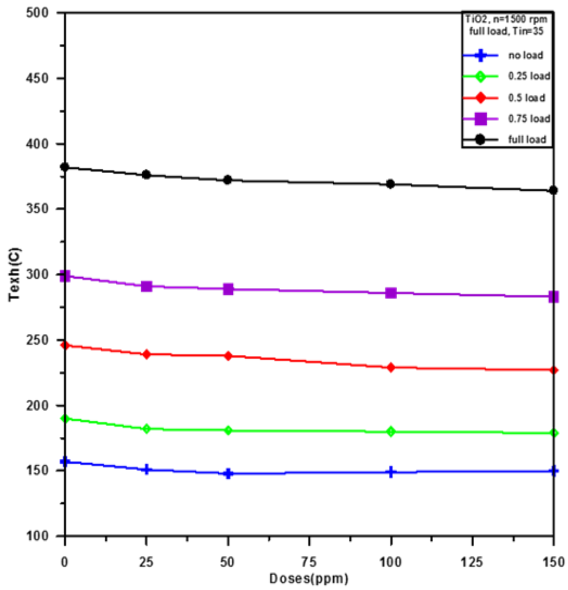


Fig 14: Variation of the exhaust temperature with nanoparticles dose.

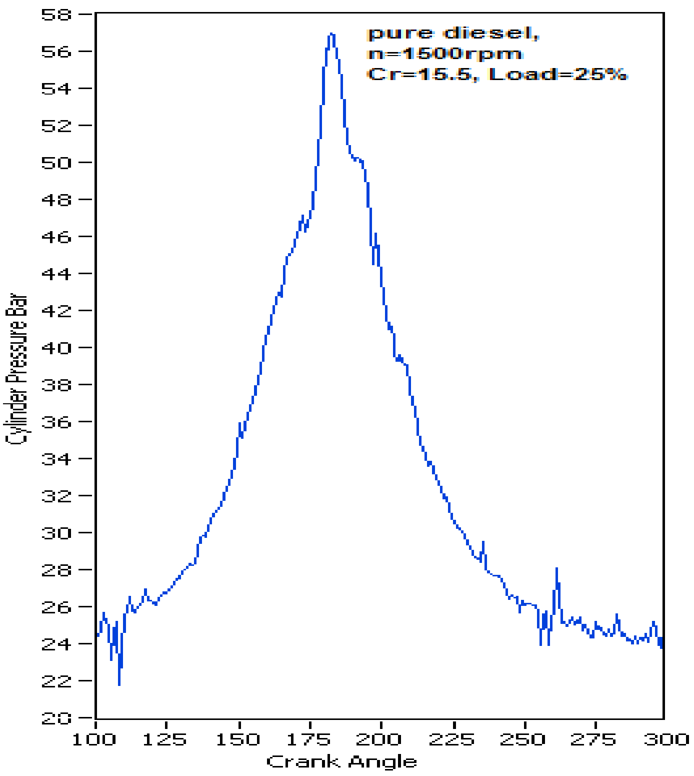


Figure (15) Cylinder Pressure History for Pure Diesel

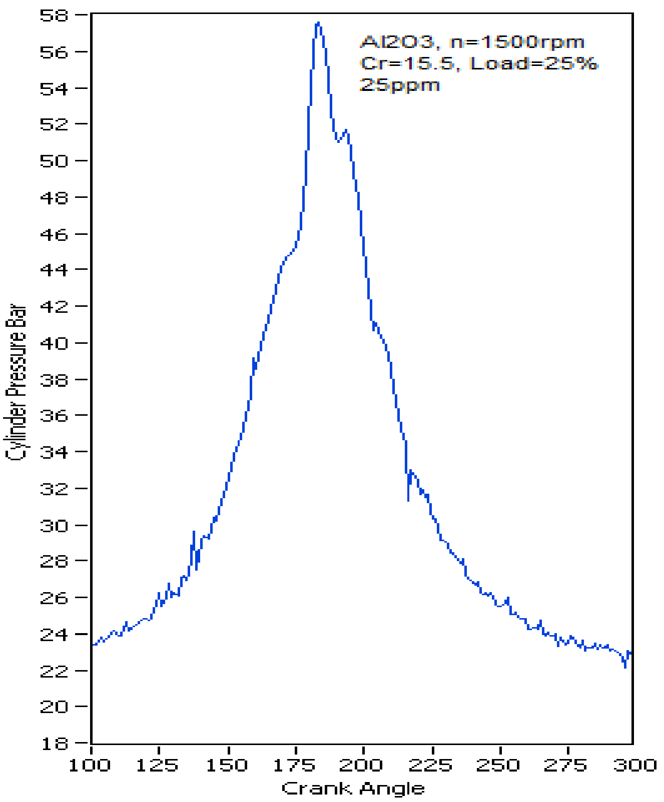


Figure (16) Cylinder Pressure History for DF+ 25ppm Al_2O_3

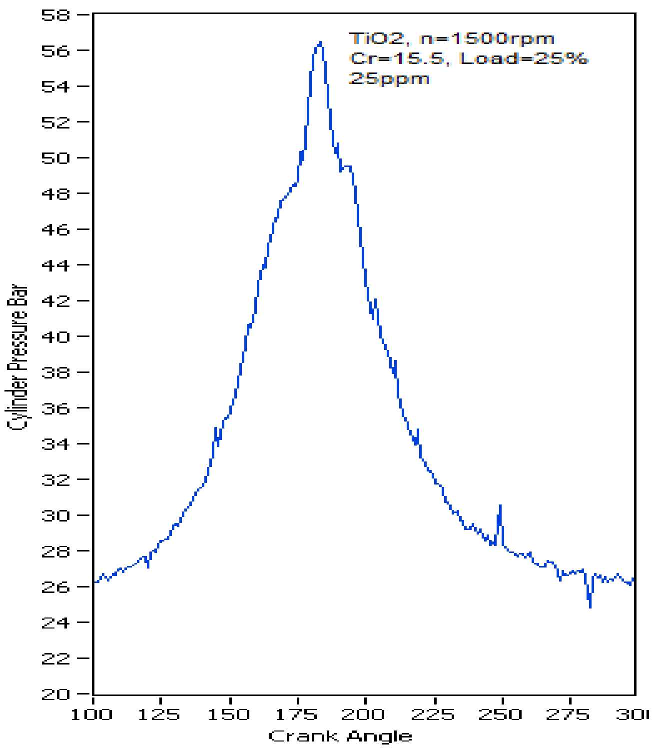


Figure (17) Cylinder Pressure History for DF+ 25ppm Tio_2

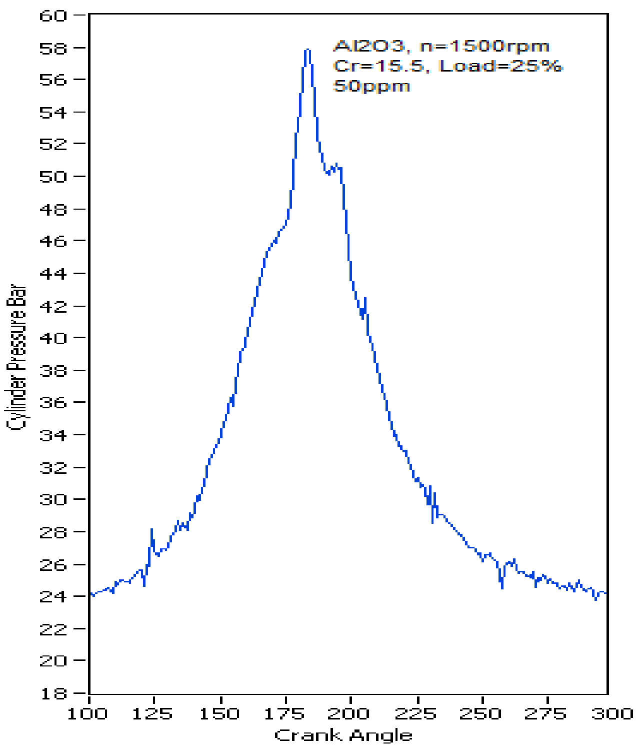


Figure (18) Cylinder Pressure History for DF+ 50ppm Al_2O_3

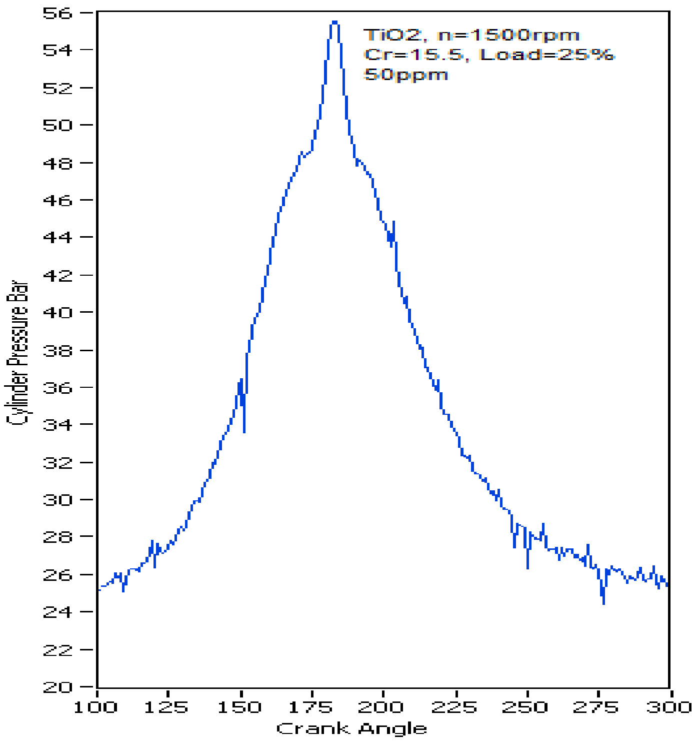


Figure (19) Cylinder Pressure History for DF+ 50ppm Tio_2

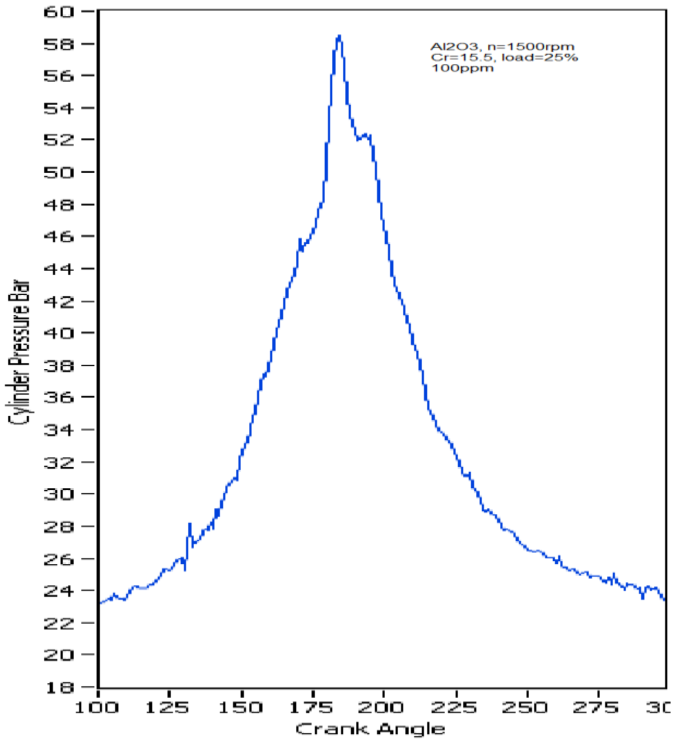


Figure (20) Cylinder Pressure History for DF+ 100ppm Al_2O_3

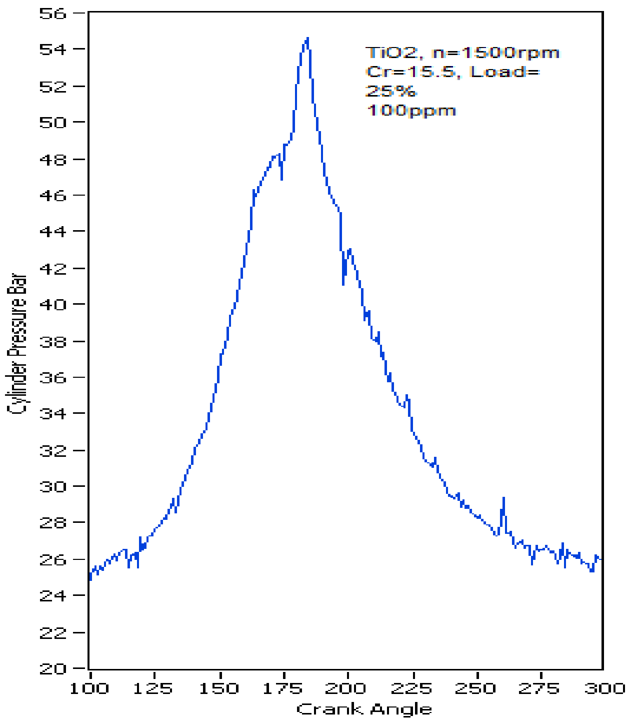


Figure (21) Cylinder Pressure History for DF+ 100ppm Tio_2

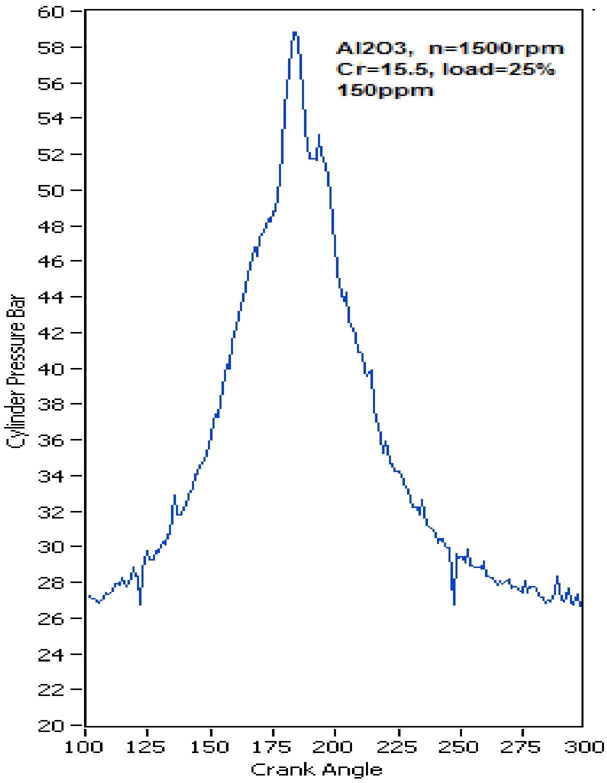


Figure (22) Cylinder Pressure History for DF+ 150ppm Al_2O_3

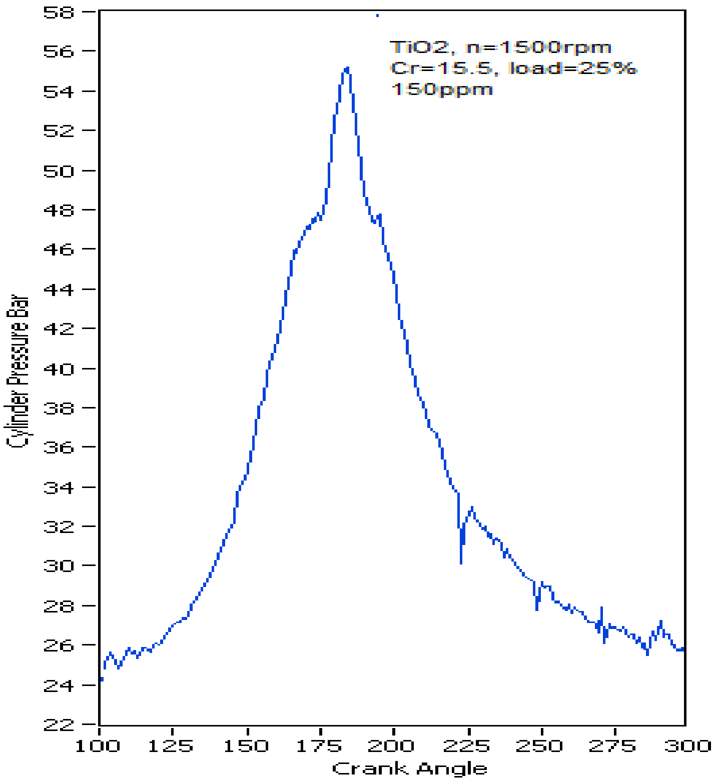
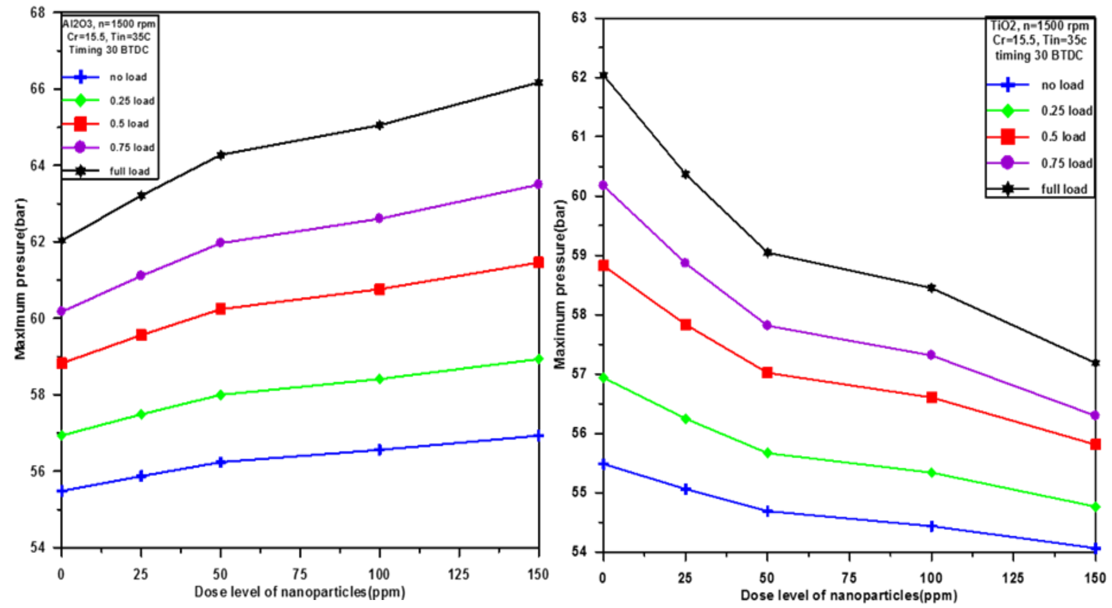


Figure (23) Cylinder Pressure History for DF+150ppm Tio_2



Figs 24 &25: Variation of the maximum pressure with nanoparticles dose

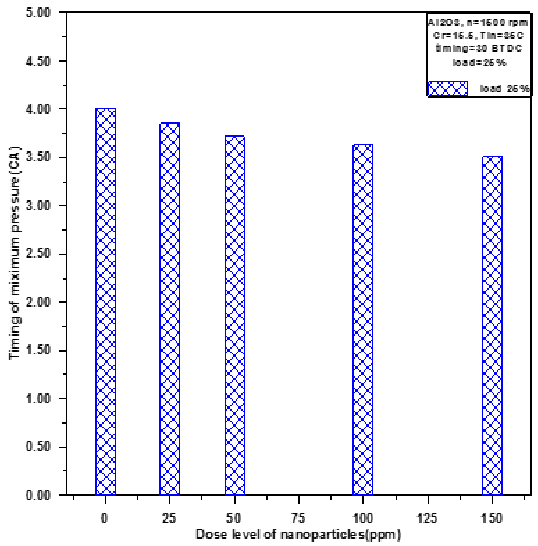


Fig 26: Variation of the timing of maximum pressure with dose of nanoparticles.

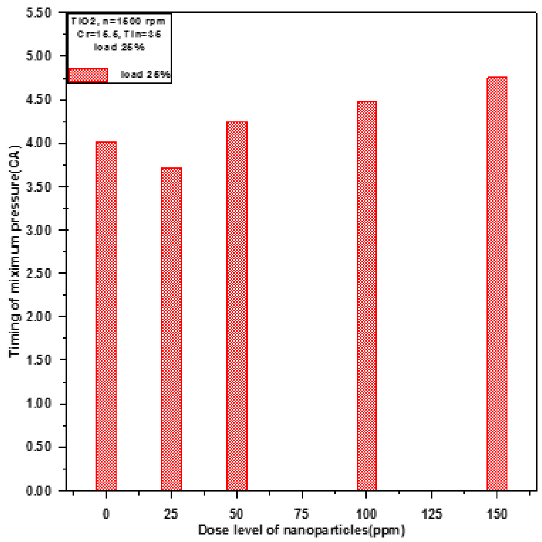


Fig 27: Variation of the timing of the maximum pressure with dose of nanoparticles.

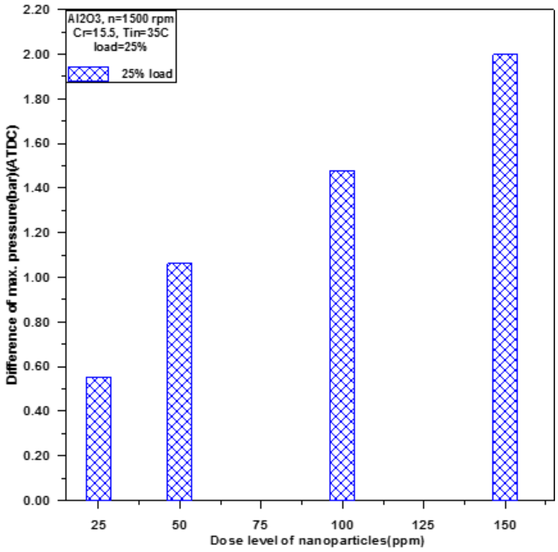


Fig 28 Variation of Δp_{max} with Nanoparticles Dose

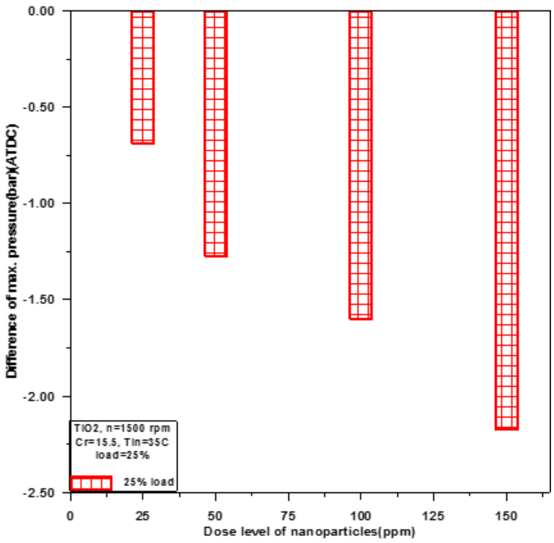


Fig 29 Variation of Δp_{max} with Nanoparticles Dose

دراسه عملية لاداء محرك ديزل يعمل بانواع مختلفه من وقود الديزل النانوي

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الخلاصة

تم في هذا البحث دراسه عمليه حول تاثيراضافة حبيبات متناهيه في الصغر (حبيبات النانو) الى وقود الديزل و تاثير ها على اداء المحرك.تم استخدام نوعين من حبيبات النانو وهما اوكسيد الالمنيوم واوكسيدالتيتانيوم وباربعة تراكيزوبنسب حجميه وهي(25، 50، 100، 150) جزء واحد لكل مليون جزء وبقطر اقل من 50 نانومترعند احمال ،سرع ونسب انضغاط مختلفه. لوحظ زياده في الكفاءه الحراريه المكبحيه مع (ديزل+اوك سيد الالمنيوم) 21% ومع (ديزل+اوك سيد التيتانيوم) 25% مقارنة مع وقود الديزل النقي .اما استهلاك الوقود النوعي المكبحي قل20% و8% (ديزل + اوكسيد التيتانيوم) و(ديزل+اوكسيد الالمنيوم) على التوالي وعند تركيز25 وحمل75%.وكذلك تحسن استهلاك الطاقه النوعي المكبحي حوالي 7%و 20% (ديزل+اوكسيد الالمنيوم) و(ديزل+اوكسيد التيتانيوم) على التوالي ولنفس الظروف.وزادت درجة حرارة العادم من382 م°للديزل الى 417 م°مع (ديزل+اوكسيد الالمنيوم) وقلت مع (ديزل + اوكسيد التيتانيوم) الى 353 م° وللديزل 382م° وللتركيز 150 وحمل كامل. اما بالنسبه لاعظم ضغط حيث كان للديزل62.03 بار وزاد مع اوكسيد الالمنيوم الى 66.2 بار وقل مع اوكسيد التيتانيوم الى 57.2 بحمل كامل وتركيز 150.

الكلمات المفتاحيه: – الوقود النانوي، حبيبات النانو، أداء المجرك، محرك الديزل.