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Research paper

The Effect of Compression Ratio on Pollutant Emission of a Diesel Engine Fuelled with Nano Diesel

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Abstract

This studying aims to examine the impact of compression ratio (CR) on the pollutants of a compression ignition engine (CIE) fuelled with Nano-diesel. Nano-particles of Al_2O_3 and TiO_2 are used as additives to diesel fuel with particle size less 45 nm. The impact is tested for 25, 50, 100 and 150 ppm doses. Tests are performed at different loads and a speed of 1500 rpm. Three CR are used namely13.5, 15.5 and 17.5. Results illustrated the affects of CR on the emissions of CO, CO_2, NO_x, smoke opacity and UHC. Results showed that CO concentration rises with increasing of CR for Al_2O_3. It is increased by 2.5, 4.9 and 15.3% for the three ratios at 100ppm and 25% load while at full load there is no much effect as a result of high combustion temperature. Negligible effect is noticed for TiO_2.The concentration of CO_2rises with increasing CR at all dozes but it is very clear with 150ppm and 25% load3.7, 4.1 and 4.8% for Al_2O_3. The effect of TiO_2 is higher than that of Al_2O_3. The results also, show that NO_x concentration is increased and becomes 604, 651 and 698ppm for 13.5, 15.5 and 17.5 respectively for Al_2O_3 at 25ppm and 25% load. The impact of Al_2O_3 is more noticeable than that of TiO_2.The smoke opacity is slightly affected by CR for Al_2O_3 and TiO_2 at all doses and 25% load. UHC decreases slightly from 79, 75 and 71 ppm for CR of 13.5, 15.5 and 17.5 respectively for Al_2O_3 at 25ppm and 25% load. UHC decreases from 68, 65 and 61 ppm for CR13.5, 15.5 and 17 respectively for TiO_2 at 25ppm and 25% load.

Keywords: *-CR, Nano diesel, Nano-particle, Exhaust emission.*

1. Introduction

Air pollution due to combustion emissions is a problem of intense concern because of exposure of large number of people to it. However vehicular emission is responsible for higher level of air pollutants such as NOx, CO, and other organic and inorganic pollutants including metal traces and their adverse effects on human and environmental Barman.et.al[1].

Saraee et al.[2] was able to reduce the pollutants emission concentration and fuel consumption in a diesel engine by using silver nanoparticles with miner engine modification. They attributed that to the improvement in heat transfer to fuel and longer fuel spray penetration caused by presence of Nano particles.

An experimental study was carried out byLenin.et.al [3]to analyze the effect of nanoparticles on operating characteristic of single –cylinder, air cooled and directed injection (DI) diesel engine. They used magnesium oxide and copper oxide as an additive metal. Maximum UHC was noticed at low load with small decrease at full load. The manganese additive showed a decrease in CO and NO_x emission by 37 % 4% respectively. Fang.et.al [4]studied impact of nanoparticles on the palm oil biodiesel characteristics. They usedTiO_2 nanoparticles with dosing 1 % and 5% palm oil. The emission of CO, UHC, NO_x and soot were all decreased. Rakhi.et.al[5] carried out an experimental work to study the effect of addition of energetic nanoparticles such as aluminum, iron and boron to diesel fuel on combustion process in a CIE. They found that CO concentration was reduced by 25-40% when additives are used. UHC concentration was also reduced by 8% and 4% for engine fueled with energetic Nano-fuel when compared with engine fueled with neat diesel fuel. Karthikeyan.et.al[6] tested the effect of zinc oxide nanoparticle (ZnO) on biodiesel (Pomolion stearin wax) combustion characteristics. Their tests were conducted on a single cylinder, air cooled, and stationary DI diesel engine at fixed speed 1500 rpm. The UHC, CO and smoke concentrations were decreased. Not much effect on NOx concentration was observed.

Ozguret.al[7] performed experimental testson the effect of adding Nanoparticles to the diesel fuel on the emission of NO_x. 4-cylinder, 4-stroke, naturally aspirated and water-cooled CIE was used in their study. Nine nanoparticles such as MgO, Al_2O_3, TiO_2, ZnO, SiO_2, Fe_2O_3, NiO, $NiFe_2O_4$ and $ZnO0.5NiO0.5Fe_2O_2$ were used. They found that addition of all nanoparticles expect $A1_20_3$ led to a reduction in the NO_x emission. The maximum reduction was found at 100 ppm dosing of MgO.

Prabakaran B. [8] studied experimentally the effect of ZnO Nano particles on CIE pollutants concentration and performance. He found that there was a reduction in NO_x and smoke concentrations. Gnanasik.et.al[9] tested experimentally the impact of Al_2O_3Nano-particles addition to methyl ester of Neem oil fuel on combustion process in a direct injection CIE. Three dozes of Al_2O_3 nanoparticles were used, namely, 100 ppm, 200 ppm and 300 ppm. The size of nanoparticles was (1 to 110 nm). The performance and emission were studied on a 4-stroke, stationary, water cooled CIE a speed of 1500 rpm and 3.5 kW power. The results showed that nanoparticles reduced NO_x by 3.12%, 7.15% and 4.97% for the three doses respectively. Jeryrajkumar.et.al [10] studied experimentally the impact of nanoparticles additions to biodiesel on engine emissions.

They used (Co_3O_4) and (TiO_2) as nanoparticles. The test were performed ona 4-stroke, water cooled CIE. It was found that (CO) concentration was decreased by 30% and 25% for (Co_3O_4) and the (TiO_2) respectively. UHC was dropped by 80%, 70% for (Co_3O_4) and (TiO_2) respectively.

Gumus et al. [11] investigated the impact of Al_2O_3 and CuO on performance and pollutants concentration of a diesel engine. They found that there was a reduction in fuel consumption and a reduction in pollutants emission.

Nasir [12]analyzed experimentally the effect of adding Al_2O_3 and TiO_2nanoparticles to diesel fuel on combustion process in a single cylinder CIE. The results indicated that emissions like carbon monoxide concentration was reduced by 40% and 46%,while CO_2 was increased by 6.7% and 8% for Al_2O_3 and TiO_2 respectively for the lowest dose at three quarters load. The nitrogen oxide NO_x was increased with Al_2O_3 from 1013ppm to 1055 ppm, while it was decreased with TiO_2 from 1013ppm to 906ppm at full load and 25 ppm. The smoke opacity was decreased by 28% and 25% for TiO_2 and Al_2O_3 respectively. The UHC was increased with Al_2O_3 and decreased with TiO_2at full load and lowest dose.

2. Experimental Set up

A series of tests are carried out to investigate the impact of nanoparticles addition on combustion emission of a CIE. The engine specifications can be found in ref **[13].**Fig (1) illustrates the experimental facility set up. The pressure history diagram, the engine RPM and temperature of exhaust gases recorded.

3. Measurement Instrumentation

The exhaust Gas analyzer type 953254 has been used for measuring CO, UHC, and CO_2 in engine exhaust by the principle of non-dividing infrared absorption and for measuring NO_X and O_2 by the principle of electrochemical cell. A smoke meter BOSCH model MED 001 is used to measure, display and print out smoke concentration in the exhaust gases **[14]**.

4. Nano-diesel Preparation

The chemical formula of fuel used is($C_{12.3}H_{22.2}$). The related properties fuel and Nano particles are shown in table (1). The nanoparticles have a particle diameter less than 45 nm. The used doses are 25, 50, 100 and 150 ppm. The required particles quantity for each test is calculated using the following formula(1) **[15].**

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

Table (2) shows the required quantity of particles for each test.

Table 1: The Physical Properties [16]

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	9
Diesel	844.3	2.778		

Each quantity of nanoparticles is mixed with (5 L) neat diesel and stirred for one hour by a stirrer and then for six hours in an ultrasonic cleaner type (JTS-1018)to ensure the through mixing and prevent aggregation [12].

Table 2: Quantities of Nano-Particles

Volume ratio (ppm)	ϕ%	Quantity of particles (kg) (Al_2O_3)	quantity of particles (kg) (TiO_2)
25	0.0025	0.4963x10^{-3}	0.529 x10^{-3}
50	0.005	0.993 x10^{-3}	1.058 x10^{-3}
100	0.01	1.986 x10^{-3}	2.116 x10^{-3}
150	0.015	2.979 x10^{-3}	3.174 x10^{-3}

5. Results and Discussions

For easy presentation and discussions, the results are divided into sub-sections as below.

5.1. Carbon Monoxide (CO)

Fig (2) showsthat the concentration of COincreases with the increase of CR. It is increased by (2.5%, 4.9% and 15.3%) for (13.5, 15.5 and 17.5) respectively for DF+Al_2O_3 at 100ppm and 25% load because of lack of oxygen and incomplete combustion, while fig(3) shows that there is no much effect for CRat full load because of the high temperature. Fig (4) shows that no much change in CO concentration with the increasing of CR with DF+TiO_2 because of a good mixing and complete combustion at 150 ppm and 25% load. Fig(5) shows same trendsat full load.

5.2. Carbon Dioxide (CO_2)

Fig (6) shows that CO_2increases with the increasing of CR for all dozes of Al_2O_3 for example with 150ppm and 25% load the concentration are 3.7%, 4.1% and 4.8% for 13.5, 15.5 and 17.5respectively. Fig(7) shows that $CO_2$is increased by 5.7, 6.8 and 7.8) for (13.5, 15.5 and 17.5) respectively for DF+Al_2O_3 at 150ppm and full load. This is due to complete combustion which generates high temperatures. Fig (8) shows that CO_2 increases with the increasing of CR with all dozes of DF+TiO_2.At 150ppm and 25% load it is 3.5%, 3.7% and 4.5% for 13.5, 15.5 and 17.5 respectively while it is increased by 6.3%, 7.5% and 8.7% for 13.5, 15.5 and 17.5 respectively for DF+TiO_2 at 150ppm at full load, as shown in fig (9).

5.3. Nitrogen Oxides (NO_x)

Fig (10) showsthat NO_xincreases as 604, 651 and 698 ppm for CR of 13.5, 15.5 and 17.5 respectively for DF+Al_2O_3 at 25ppm and 25% load. This is due to the enhancement in temperature as the CR increases. Similar trend is noticed at full load as illustrated in fig (11).It is noticed that the NO_x concentration rises with increasing CR for DF+TiO_2 as in figs (12 and 13).However, it is indicated that the effect of Al_2O_3 is more noticeable than that of TiO_2.

5.4. Smoke Opacity

Figs (14, 15, 16, 17) show that both Nano-particles have large impact on reducing smoke opacity. However, there is negligible effect of CR on smoke opacity for both DF+$Al_2O_3$and DF+TiO_2at all loads because both types improve mixing process of air and fuel which improves combustion efficiency.

5.5. Unburnt Hydrocarbon (UHC)

Figs (18 and 19) shows small decrease in UHC concentration as the CR increases for DF+Al_2O_3at part load and full load conditions. Same trends are noticed for DF+TiO_2 at both part and full loads conditions as shown in figs (20 and21).

6. Conclusions

1. CO emission increases with the increasing of CR with Al_2O_3 but little effect is noticed with TiO_2.

2. CO_2 increases with the increasing of compression ratio for both types of nanoparticles.
3. NO_x emission increases with the increasing of compression ratio.
4. Effect of CR is negligible on smoke opacityfor both types of Nano-particles.
5. UHC concentration decreases slightly with the increase of CR for both types of Nano-particles.

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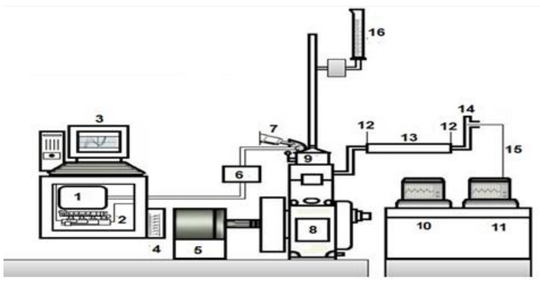

1	Air surge tank	7	Fuel injector	13	Calorimeter
2	Data Logger	8	Engine block	14	Silencer tip
3	PC	9	Cylinder head	15	Exhaust gas probe
4	Water manometer	10	Gas analyzer	16	Fuel tank
5	Eddy current	11	Smoke meter		
6	Intake air	12	PT-100 sensor		

Fig. 1: Schematic Diagram of Experimental Set Up.

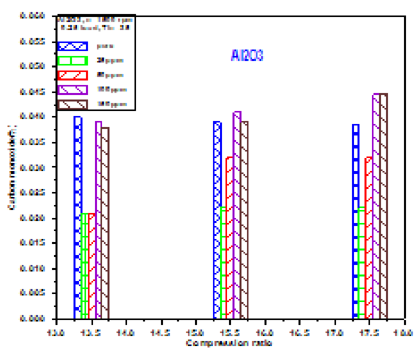

Fig. 2: Variation of CO with the compression ratio at Part Load Conditions

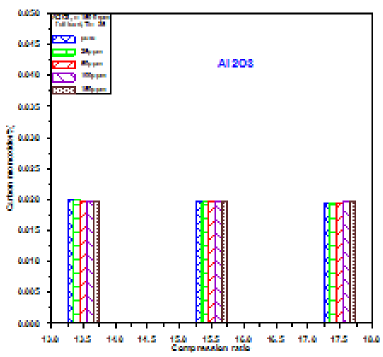

Fig. 3: Variation of CO with the compression ratio at Full Load Conditions

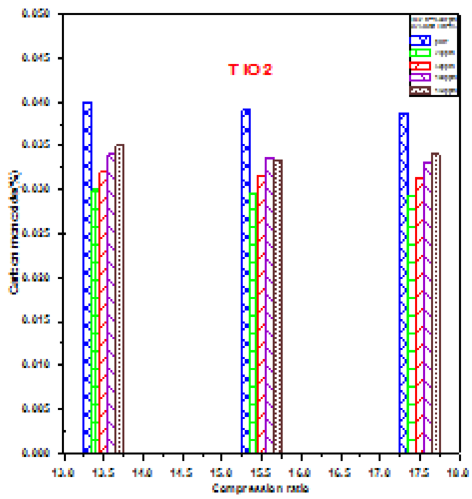

Fig. 4: Variation of CO with the compression ratio at Part Load Conditions

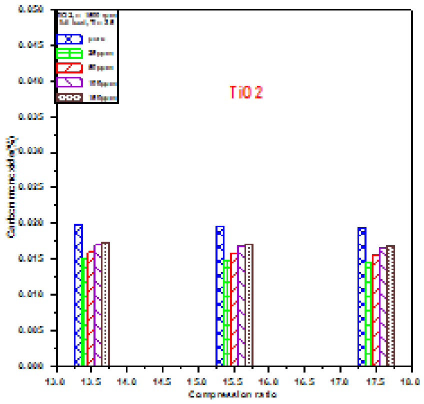

Fig. 5: Variation of CO with the compression ratio at Full Load Conditions

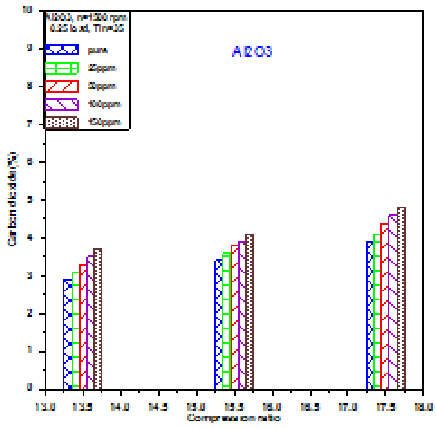

Fig. 6: Variation **of** CO_2 with the compression ratio at Part Load Conditions

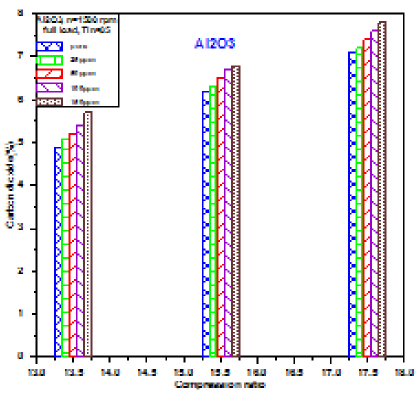

Fig. 7: Variation of $\mathbf{CO_2}$ with the compression ratio at Full Load Conditions

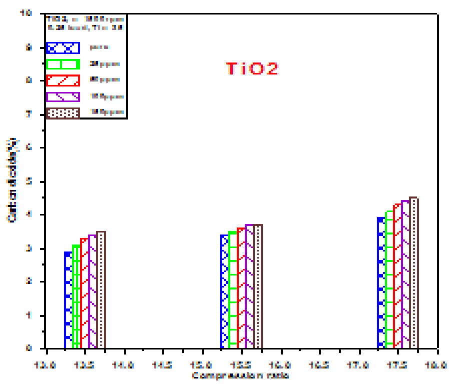

Fig. 8: Variation of CO_2 with the compression ratio at Part Load Conditions

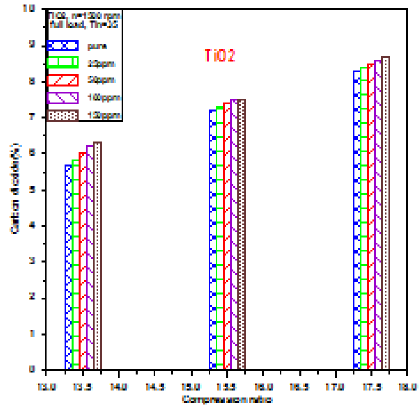

Fig. 9: Variation of CO_2 with the compression ratio at Full Load Conditions

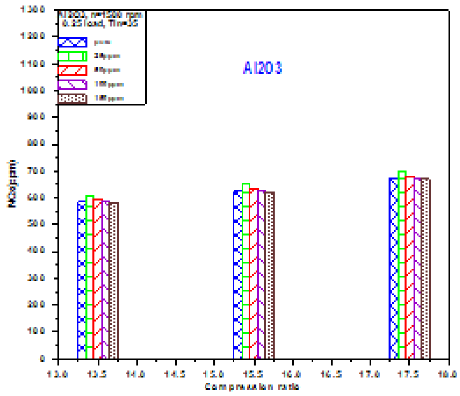

Fig. 10: Variation **of** NO_x with the compression ratio at Part Load Conditions

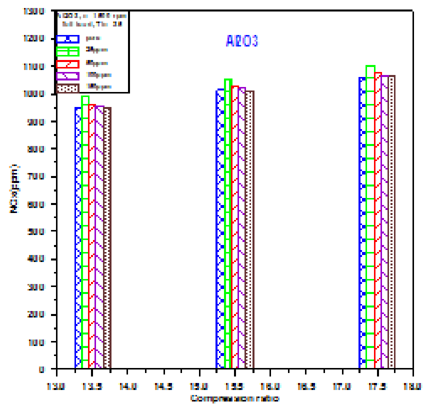

Fig. 11: Variation of NO_x with the compression ratio at Full Load Conditions

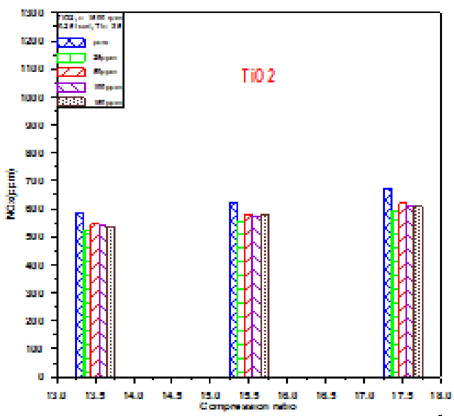

Fig. 12: Variation of NO_x with the compression ratio at Part Load Conditions

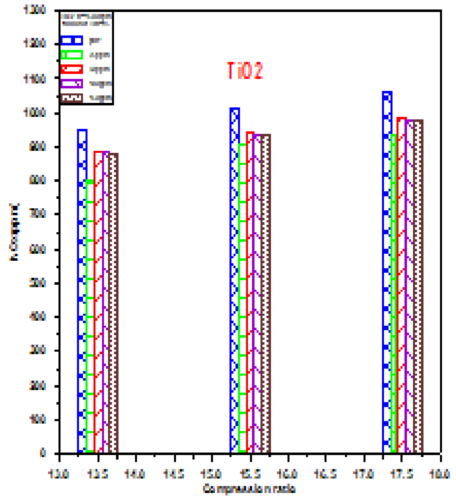

Fig. 13: Variation of NO_x with the compression ratio at Full Load Conditions

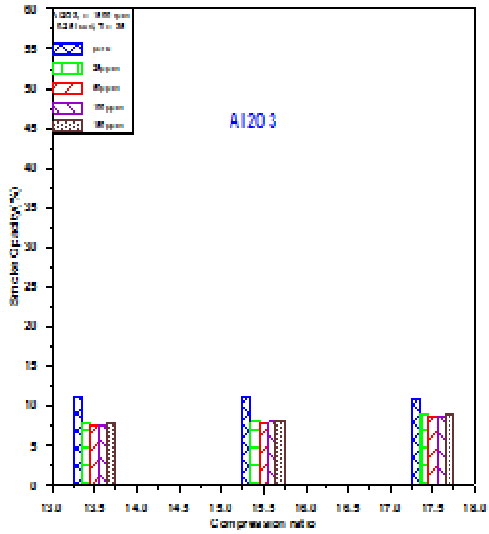

Fig. 14: Variation of smoke opacity with the compression ratio at Part Load

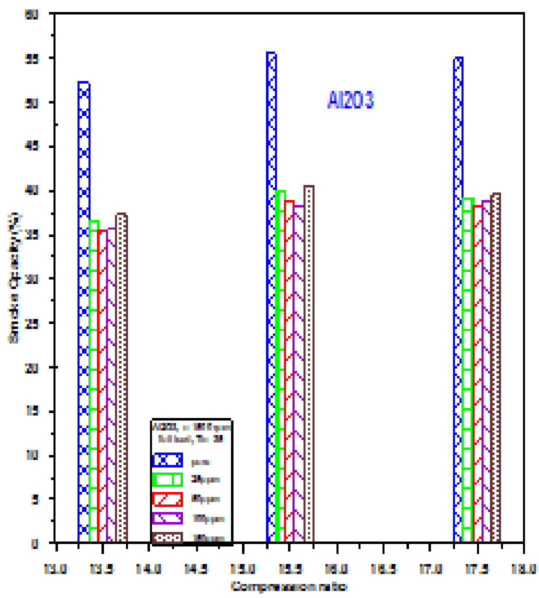

Fig. 15: Variation of smoke opacity with the compression ratio at Full Load Conditions

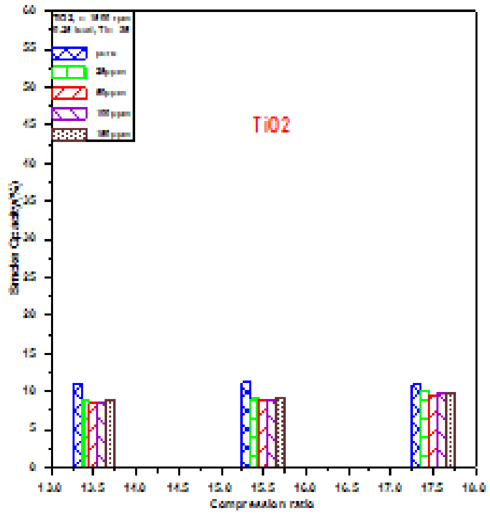

Fig. 16: Variation of smoke opacity with the compression ratio at Part Load Conditions

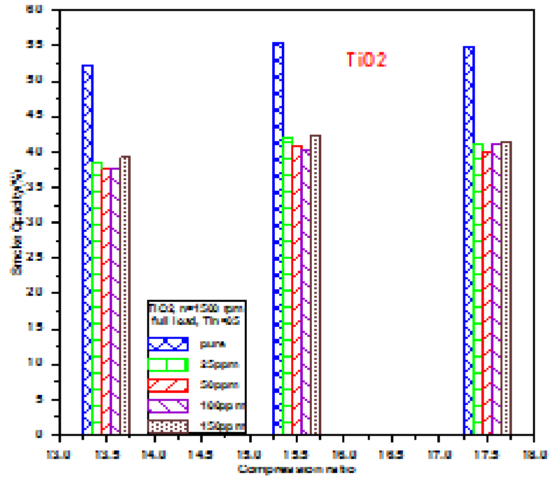

Fig. 17: Variation of smoke opacity with the compression ratio at Part Load Conditions

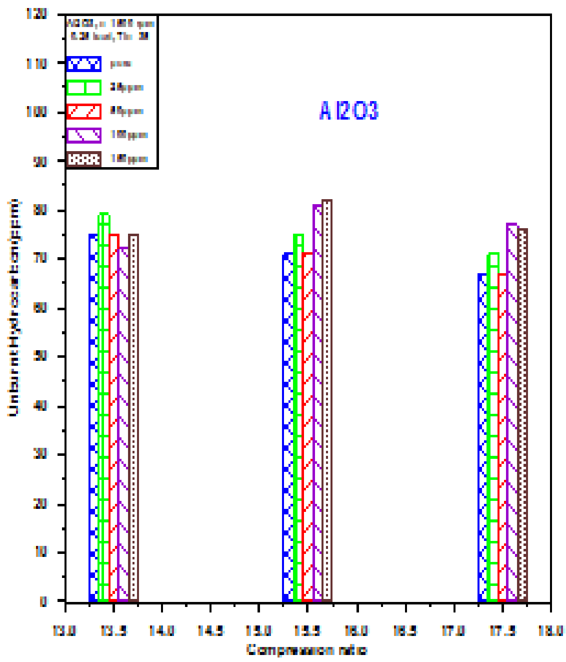

Fig. 18: Variation of UHC with the compression ratio at Part Load Conditions

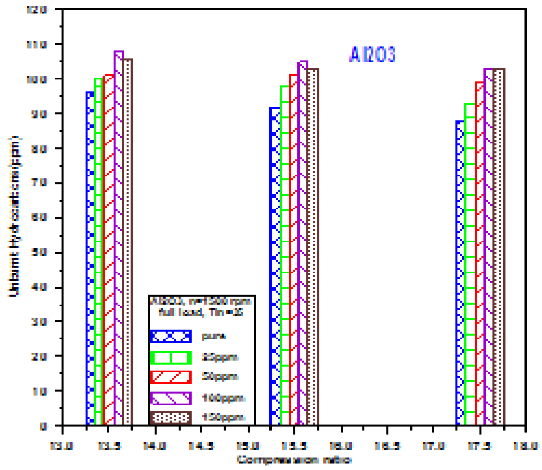

Fig. 19: Variation of UHC with the compression ratio at Full Load Conditions

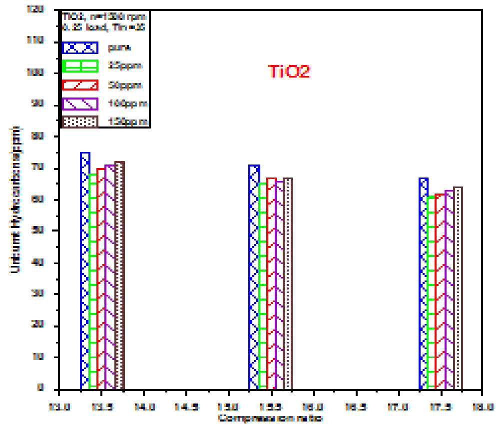

Fig. 20: Variation of UHC with the compression ratio at Part Load Conditions

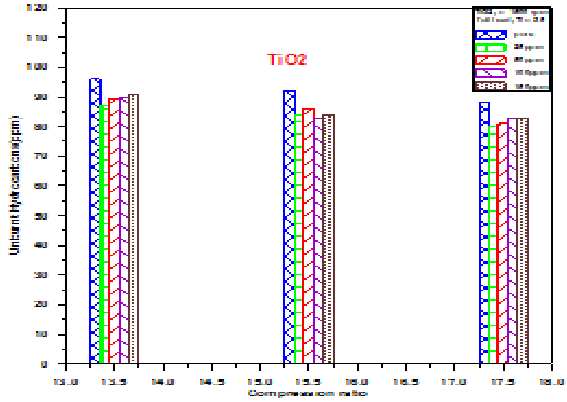

Fig. 21: Variation of UHC with the compression ratio at Full Load Conditions