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Performance and Emission Characteristics of CI Engine by varying Pistons Fuelled with Pongamia Biodiesel and Zinc Oxide Nano Fluid as Additive

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Abstract:-- **The main reason for the investigation of usage of alternate fuels in internal combustion engines was due to rapid increase in urbanization, usage of automobiles leads to the depletion of petroleum products, increase in emission of exhaust gases has increased. The emissions coming from engines cause severe harm to environment. So to overcome this problem government had lay down strict regulations to the engine manufacturers and consumers to follow emission norms. In this regard, alternate fuels came into existence after various investigations of many researchers. The various alternate fuels derived from plants and vegetables are such as pongamia, jatropha, soybean, mahua oil, rice bran oil, palm, neem etc. considered as potential alternatives for heavy vehicles. The direct usage of vegetable oil in diesel engine is restricted because of their high viscosity, poor atomization, incomplete combustion and carbon deposition on the fuel injectors. The viscosity of vegetable oil reduced by the process of transesterification by converting vegetable oil into methyl ester or ethyl ester known as biodiesel. The objective of this paper is comparision of performance and emissions of diesel engine with diesel and blending of biodiesel by using nano fluid as additive. In this study the comparison of performance and emission characteristics of internal combustion engine of different pistons with provision of different shapes of grooves on the piston crown. Experimental work has done on single cylinder diesel engine with blending of pongamia biodiesel with diesel and by using nano fluid at different proportions as additive which it is used for improving the engine performance.Further calculating the performance and emissions like CO, NOX, HC of single cylinder engine with pongamia biodiesel as a fuel by varying pistons and by varying nano fluid proportion.**

Keywords:— **Diesel, Pongamia biodiesel, Zinc Oxide, Different pistons, Performance, and Emissions**

I. INTRODUCTION

Diesel engines are the major source for transportation, marine applications etc. due to rapid urbanization and increasing in utilization of technology leads to depletion of petroleum products. This had a serious impact on environmental pollution and there is a need of alternative sources of energy. Biodiesel is one of the potential alternatives to petroleum diesel, as its properties are very comparable to diesel. Moreover, biodiesel is mainly derived from renewable feed stocks like edible, non-edible oils or animal fats. In recent decades, the main focus is to prepare biodiesel from vegetable oils like cottonseed oil, sunflower oil, coconut oil, jatropha, pongamia. the major differences between diesel fuel and vegetable oil include, significantly higher viscosity, lower heating values, higher densities, rise in the stoichiometric fuel/air ratio due to the presence of molecular oxygen and the possibility of thermal cracking at the temperatures encountered by the fuel spray in the diesel engines. Biodiesel is an oxygenated fuel which contains 10-15% oxygen by weight. Also it is said to be sulfur free fuel. These facts leads biodiesel to total combustion and less exhaust emissions than diesel fuel. Using optimized blend of biodiesel and diesel can reduce some significant percentage of the world's dependence on fossil fuels without modification of CI engine, and also it has environmental benefits. Moreover additives are an essential part of today's fuels. With the use of fuel additives in the blend of biodiesel and diesel fuelled in CI engine which furthers more improve performance, combustion, and decrease emission characteristics and also improved fuel properties which enhance the combustion characteristics.

It is well known that in DI diesel engines swirl motion is needed for proper mixing of fuel and air. Moreover, the efficiency of diesel engines can be improved by increasing the burn rate of fuel air mixture. This can be achieved in two ways; one by designing the combustion chamber in order to reduce contact between the flame and the chamber surface, and two by providing the intake system so as to impart a swirl motion to the incoming air. The swirl ratio and resulting fluid motion can have a significant effect on air-fuel mixing, combustion, heat transfer, and emissions. The interaction between the swirl motion and the squish flow induced by compression increases the turbulence levels in the combustion bowl, promoting mixing and evaporation of fuel. In diesel engine, fuel is injected at the end of compression stroke, followed by the entry of compressed air tangentially into the injected fuel spray and then it mixes with air. In order to achieve the swirl intensities in the cylinder, changes on the piston crown has been selected. To increase the swirl, series of experiments were conducted like 9 elliptical grooves piston and compare the results with normal piston.

It is observed from the literature that there were efforts to make use of neat biodiesel and to further make it feasible and effective. In the present investigation, biodiesel was produced from pongamia oil and investigation on performance and emission characteristics were evaluated using compression ignition engine and also investigated the addition of nano additive on biodiesel effects. In this zno nano fluid is taken as additive and based on literature reviews it was planned to investigate the effect of additive on performance by taking proportions like 40ppm, 80ppm, and 120ppm.

II. PREPARATION OF BIO-DIESEL

Transesterification is a chemical process of transforming large, branched, triglyceride molecules of vegetable oils and fats into smaller, straight chain molecules, almost similar in size to the molecules of the species present in diesel fuel. The process takes place by the reaction of vegetable oil with alcohol in the presence of a catalyst.

In transesterification process pongamia oil react with methyl alcohol in the presence of catalyst (Noah) to produce glycerol and fatty acid ester. The methyl alcohol (200ml) and 8 gram of Noah were taken in a round bottom flask to form sodium methoxide. Then the methoxide solution was mixed with pongamia oil (100 ml). The mixture was heated to 60°c and held at that temperature with constant speed stirring for 2 hours to form ester. Then it was allowed to cool and settle in a separating flask for 12 hours. Two layers were formed in the separating flask. The bottom layer was glycerol and upper layer was methyl ester. After decantation of glycerol, the methyl ester was washed with distilled water to remove excess methanol. The transesterification improved the important fuel properties like specific gravity, viscosity and flash point. The properties of diesel, pongamia biodiesel and b20 are listed in table 1.

Table 1.Fuel Properties

Properties	Diesel	Biodiesel	B20
Calorific value (kj/kg)	43000	37270	41850
Density(kg/m³)	850	900	860
Flash point °c	55	144	66
Fire point °c	59	155	72
Kinematic viscosity(m²/s)	3.9	4.6	4.1

III. EXPERIMENTAL SETUP

The experimental setup consists of 4 stroke diesel engine which is to be tested for performance is connected to the rope brake dynamometer and calorimeter. The equipment consists of kirloskar diesel engine (crank started) of 5hp (3.7kw) capacity and is water cooled. The engine is coupled to a rope brake drum dynamometer for loading purposes. Coupling is done by an extension shaft in a separate bearing house.

Fig.1 experimental setup

The dynamometer is connected to the spring load assembly for varying the load. The engine operated at speed 1500 rpm with compression ratio 16.5:1. Thermocouples are provided at appropriate positions and are read by a digital temperature indicator with channel selector to select the position. Rota meter is used for direct measurement of water flow rate to the engine and calorimeter respectively. Engine speed and the load applied at various conditions is determined by a digital rpm indicator and spring balance reading. A volumetric flask with a fuel distributor is provided for measurement and directing the fuel to the engine respectively. Thermocouples are used to measure exhaust gas temperature. Emissions like co, NOX, and hc are measured by using exhaust gas analyser.

Experiments are conducted with pure diesel, diesel blend of pongamia for b20 and with blend of diesel and biodiesel by using zno nano fluid as additive.the effects are plotted against brake power (BP). The experimental set up is shown in fig.1.

Table 2. Engine specification

type	Single cylinder, four stroke, water cooled internal combustion diesel engine
CapaCIty	553 cc
Bore x stroke	80 mm x 110mm
Compression ratio	16.5:1
Speed	1500rpm
Rated power	5 hp
Make	Kirloskar
Strarting	By hand cranking

IV. EXPERIMENTS WITH GROOVED PISTONS

Firstly allow the engine to run for about 20 min with normal piston, so that it gets warmed up and steady running conditions are attained. The experiments were conducted in diesel engine with grooved pistons of proposed configuration to know the performance of the diesel engine. Further the experiment was carried on the diesel engine with blending of pongamia biodiesel and diesel with different proportions of zinc oxide as additive. The test is carried on the kirloskar diesel engine for the following

- ❖ Normal piston
- ❖ Epg9 elliptical grooved piston

Fig.2 normal piston

Fig.3 elliptical groove piston

V. RESULTS AND DISCUSSION

a) brake thermal efficiency

Fig.4 shows the variation of the brake thermal efficiency with brake power for diesel, b20 and b20 with nano fluid additive with different proportions. The thermal efficiency obtained for diesel and b20 are 36.13%,31.3%

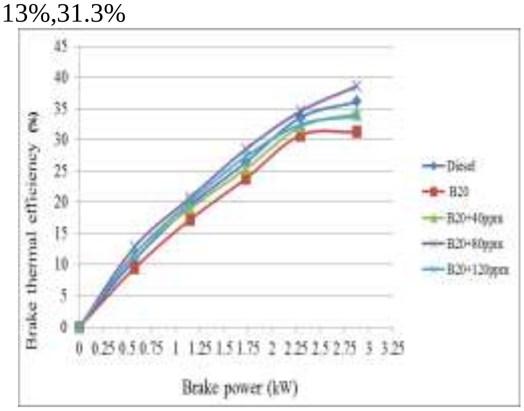

Fig.4 variation of brake thermal efficiency with BP

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Respectively at full load. The decrease in thermal efficiency for b20 when compare to diesel is due to lower calorific value, higher viscosity and ineffective utilization of heat energy due to higher molecular weight of methyl ester. Whereas for b20 with ZNO for 40ppm, 80ppm and 120ppm are 34.24%,38.63 and 33.82%.the increase in thermal efficiency when b20 is added with additive of 40ppm and 80ppm when compare with b20 and diesel was due to sufficient oxygen content present in nano fluid. Due to this it forms homogeneous mixture and proper combustion takes place and leads to higher thermal efficiency.

B) Brake specific fuel consumption

Fig.5 shows the variation of specific fuel consumption with brake power for diesel, b20 and with b20 when added with additives. The sfc values obtained for diesel and b20 are 0.232 kg/kwhr and 0.253 kg/kwhr respectively, whereas for b20+40ppm,b20+80ppm and b20+120ppm the values are 0.239,0.23 and 0.254.the increase in sfc for b20 is due to high density and viscosity, which leads to effect of mixture formation further leads to slow combustion. When zno is used as additive for 80ppm sfc is reduced than diesel at full load, this is due to catalytic chemical oxidation of fuel which leads to improve the combustion of fuel. For 120ppm sfc is increased than diesel due to lean mixture. So for b20+120ppm speCIfic fuel consumption is more than diesel.

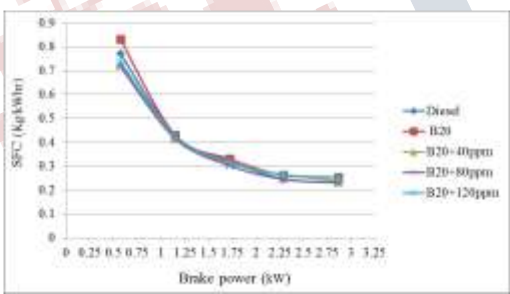

Fig.5 variation of SFC with BP

Emission characteristics

C) Hydrocarbon emission (HC)

Fig.6 depicts the variation of hydrocarbon emission with brake power for diesel, b20 and b20 with nano fuel additive. Hydrocarbon emission was slightly increased for b20 when compare with diesel. The values obtained are 28ppm and 31ppm.the increase in emission for b20 at full load is due to enough oxygen is not present and it forms rich micture.so incomplete combustion takes place hence increase in emissions. When compared b20 mixed with

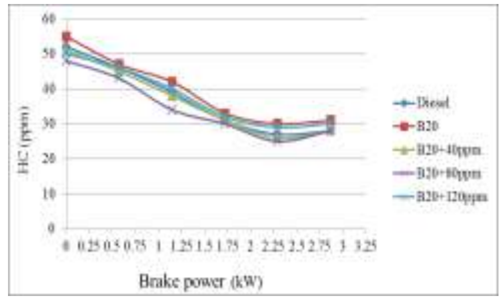

Fig.6 variation of HC emissions with BP

Nano fluid for b20+80ppm yields minimum emissions than diesel. The reason is, due to presence of oxygen content in additive that makes homogeneous mixture and results in complete combustion. Thus reductions of hydrocarbon emissions are observed for b20+80ppm.

D) Carbon moNOXide emission (co)

Fig.7 illustrates the variations of carbon moNOXide emissions with brake power. Generally co emissions occur due to fuel rich combustion and insufficient time. The emission values obtained for diesel and b20 at full load condition are 0.07% and 0.08%.the increase in co emissions for diesel are due to lack of oxygen or due to engine running in too rich condition. The decrease in emission level for diesel is due to presence of 10 to 11% of oxygen content than in biodiesel. By adding additives for b20+80ppm has obtained lower emission when compared to diesel. The values obtained are 0.075%, 0.05% and 0.07% for b20+40ppm,b20+80ppm and b20+120ppm.the emissions reduced at 80ppm at full load due to the oxygen present in additives and forms stoichiometric mixture and complete combustion takes place with less emissions of co.

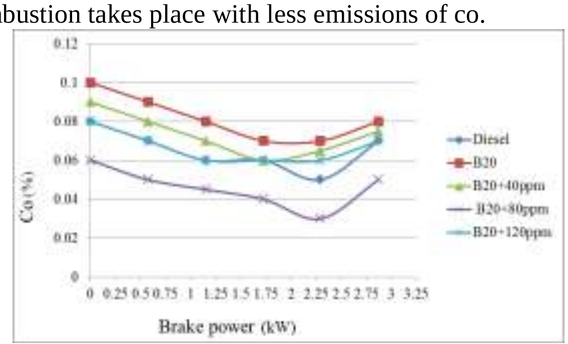

Fig.7 variation of co emissions with BP

E) Nitrogen oxide emission (NOX)

The differences of NOX emission for diesel, pongamia biodiesel and pongamia biodiesel with nano-fuel additives with brake power shown in fig.8. Mostly NOX emissions forms due to higher combustion temperature and other factors like injection timing, lack of oxygen and combustion quality. The obtained NOX emissions for diesel b20,b20+40ppm,b20+80ppm and b20+120ppm are 842ppm,812ppm,861ppm,869ppm and 871ppm.the NOX emission is found to be minimum for b20 when compared with other biodiesel nano-fuel additives and higher than diesel. This is due to change in the combustion temperatures.

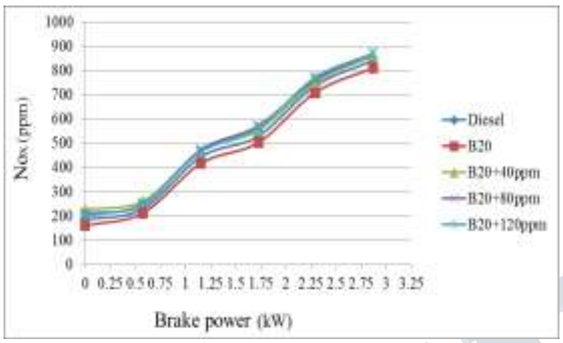

Fig.8 variation of NOX emissions with BP

F) Exhaust gas temperature

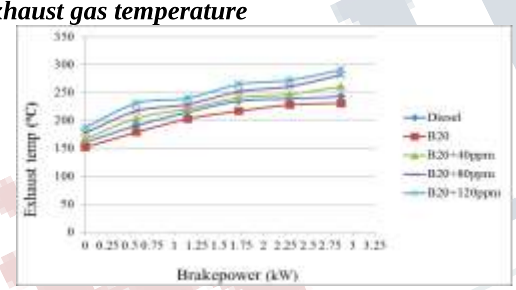

Fig.9 variation of exhaust gas temperature with BP

from the graph the variation of exhaust gas temperature with brake power for diesel, b20 and for biodiesel with nano fuel additives are obtained as 243°c,231°c,261°c,282°c and 291°c.the temperature values increased for all b20+40ppm,b20+80ppm and b20+120ppm when compare with diesel. Due to combustion rate increases at full load, the exhaust gas temperature obtained is also higher at full load.

Results for aluminium and elliptical grooved pistons

A) Brake thermal efficiency

Fig.10 shows the variation of brake thermal efficiency with brake power for aluminum piston and aluminum +eg9 piston. Maximum brake thermal efficiency was obtained for aluminum +e9 piston when compared with aluminum piston. The obtained values are 38.63 and 41.32 for aluminum and aluminum +e9 piston. The increase in brake thermal efficiency for aluminum+e9 piston was due to grooves present on the piston head. Due to this swirling action takes place and homogeneous mixture is formed.

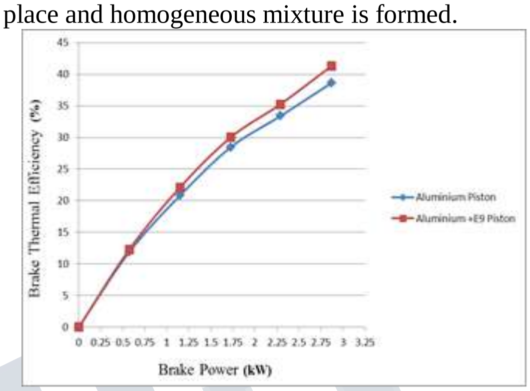

Fig.10 variation of brake thermal efficiency with BP

B) Brake specific fuel consumption

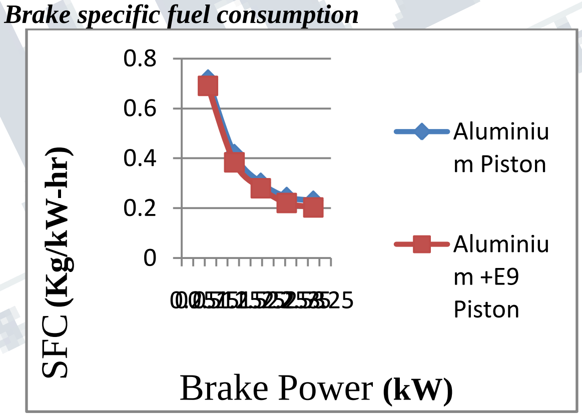

Fig.11 variation of sfc with BP

Fig.11 shows the variation of specific fuel consumption with brake power.for aluminum piston sfc was 0.23kg/kw-hr at full load.for aluminum+e9 piston was 0.203kg/kw-hr.sfc was found to be minimum for aluminum+e9 piston at full load when compared with aluminum piston.this is due to providing elliptical shape grooves on the piston surface.due to this fuel will be distributed equally and effectively and all fuel will combines with air in a homogeneous manner,hence no fuel will be wasted and complete combustion takes place.the products of combustion will be completely swiped away.

Emission characteristics

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C) hydrocarbon emission (HC)

The variation of hc emissions with BP was shown in fig. 10.hydrocarbon emissions for aluminum+e9 piston was observed to be minimum when compared with aluminum piston. For aluminum+e9 piston and aluminum piston the values obtained are 24ppm and 29ppm at full load condition.

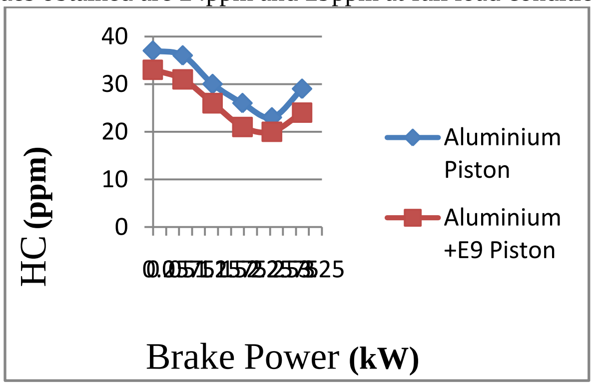

Fig.12 variation of hc emissions with BP

The decrease in hc emission for aluminum+e9 piston was due to provision of elliptical grooves.due to this swirling takes place,so by this fuel will flow in a particular directions and burns in the presence of fresh air.by this stoichiometric fuel-air ratio was formed and complete combustion takes place.

D) carbon moNOXide emission (co)

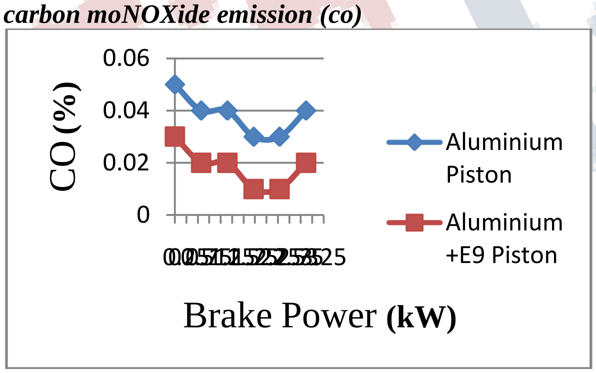

Fig.13 variation of co emissions with BP

Fig.13 shows the variation of brake power with carbon monoixde emission.the emission of co was observed to be minimum for aluminum+e9 piston than aluminum piston. By providing elliptical shape grooves the fuel undergoes swirling action and all the fuel will combines with air. By addition of zno as additive enough oxygen will present and complete combustion takes place.due to this no carbon deposits will be found.so the emission of co was reduced than aluminum piston.

E) nitrogen oxide emission (NOX)

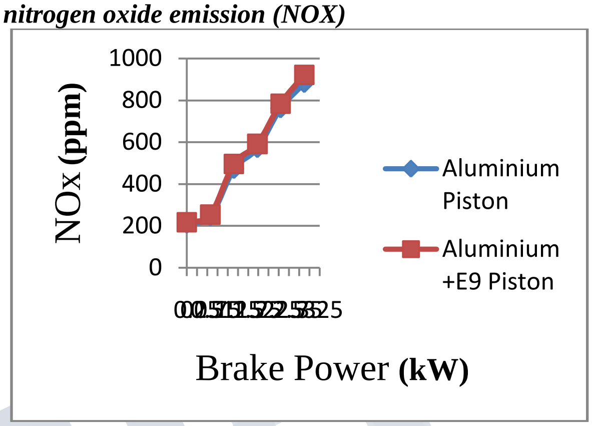

Fig.14 variation of NOX emissions with BP

The above figure depicts the behaviour of NOX emissions with change of brake power.NOX emissions.the obtained values for aluminum+e9 piston and aluminum piston are 921 ppm and 883 ppm.the increase in emission for aluminum+e9 piston was due to provision of grooves swirling action takes place.due to this complete combustion takes place,so by complete combustion exhaust gas temperatures are more.NOX emissions mostly occur due to high combustion temperature.so NOX emissions are higher for the piston with elliptical grooves.

F) exhaust gas temperature

The variation of exhaust gas temperature with brake power was shown in the fig.15.exhaust gas temperature was more for aluminum+e9 piston when compared with aluminum piston.the values obtained are 293°c and 282°c.the increase in exhaust gas temperature for aluminum+e9 piston was due to more combustion temperatures are formed due to complete combustion.complete combustion occurred due to provision of elliptical grooves on the piston head. By this swirling takes place and homogeneous mixture was formed and combustion takes place completely. Due to this higher temperature of combustion products are formed and hence exhaust gas temperature was higher for aluminium+e9 piston when compared with aluminium piston.

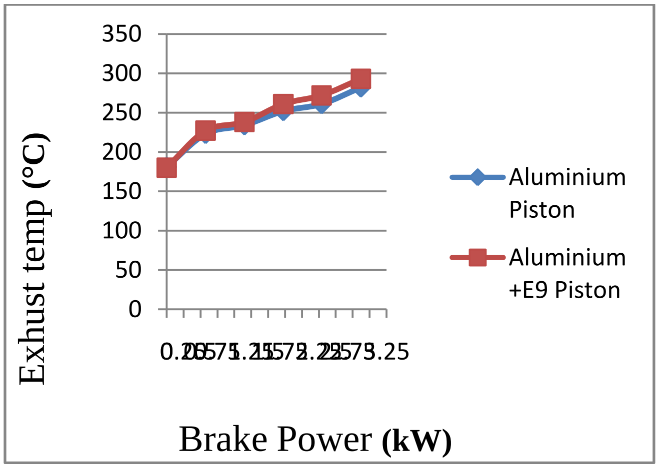

Fig.15 variation of exhaust gas temperature with BP

VI. CONCLUSION

The experiments were conducted with pongamia biodiesel and zno as a nano-fluid has been studied and investigated the performance and emission characteristics. The following conclusions based on the experiment are,

- B20 is having lower efficiency and higher energy consumption due to these results in lower heat value. The addition of nano fuel additives there is a significant increase in thermal efficiency compare to biodiesel without additives.
- The brake thermal efficiency for b20+80ppm increased by about 2.06% when compared with diesel at full load.
- The reduction in co emission by using b20+80ppm has observed when compare with diesel. The co emissions reduced by 25% when compared with diesel.
- The HC emissions are obtained minimum for b20+80ppm when compared with diesel and other biodiesel nano-fuel additives.
- NOX emissions are increased for all biodiesel nano fuel additives and for b20 when compare with diesel at full load. For b20+80ppm the emission value obtained is minimum when compare with b20,b20+40ppm and b20+120ppm and increased when compare with diesel. This is due to higher combustion temperature.
- The brake thermal efficiency was higher for aluminium+e9 piston when b20 and 80ppm of ZNO was used than aluminum piston. Brake thermal effiCIency for aluminium+e9 piston when b20+80ppm 0f zno was used has increased by 5.2% when compared with aluminum piston.
- The speCIfic fuel consumption was decreased by 11.73% for aluminium+e9 piston when compared with aluminum piston.
- Co emissions are reduced by 34% for aluminium+e9 piston when compared with aluminum piston for b20+80ppm at full load condition.
- The reduction in hc emissions has observed for aluminium+e9 piston than aluminum piston. The reduction was 17.24% when compared with aluminum piston.
- NOX emissions for aluminum+e9 piston were observed to be minimum when compared with aluminum piston. The emissions are reduced to about 4.3% for b20+80ppm at full load condition when aluminum+e9 piston was used.

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