# Experimental Analysis of Performance & Emission Characteristics of 4 Stroke single cylinder C I Engine by using Palm Seed Oil Biodiesel Blend with Magnetic Energizer

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**Abstract -** *An experimental testing on the relative change of a four-stroke, single-cylinder, direct injection, water-cooled compression ignition engine using both petrodiesel and biodiesel under the influence of a magnetic field was conducted. The engine was tested using pure petrodiesel (as reference fuel) and their blends. This was done with and without the magnetic effect under vaiable load and variable speed conditions. Results showed that biodiesel is less influenced with the presence of the magnetic flux than diesel. Further, it was shown that engine performance enhancement is better with biodiesel than diesel without the use of a magnetic field. This study shows the comparison of performance and emission characteristics of diesel engine using diesel and magnetized biodiesel as palm seed oil with various proportions by volume (P10, P20, and P30). And in this research paper we briefly discuss replacement of fossil fuel with palm seed oil and diesel and its effect on the engine performance and emission characteristics.*

***Key Words***: Biodiesel; magnetic flux; CI engine; engine performance; Exhaust Gas Analyzer

## 1. INTRODUCTION

Vitality is indispensable for all products of life. The present world's request is met by petroleum products like gaseous petrol, oil, coal and so on. The current vitality situation has started a pushed to explore individuals to show lights on nonpetroleum, inexhaustible and non-contaminating fills. As a large portion of the car applications depend on oil based goods in this manner exhausting the accessible assets which has increased the enthusiasm of interchange fills on the planet advertise. Worldwide emanation viewpoints, burning of petroleum product cause air contamination in urban communities and corrosive down pours which harms woodlands. This prompts the development of carbon dioxide, changing the warmth parity of the earth. India's energy demand is growing as a result of the increasing population. Due to a lack of energy resources, India relies heavily on importing energy to meet the growing demand. In the current vitality situation, numerous scientists centered to successful misuse on biodiesel. Bio-diesel is the most significant type of inexhaustible vitality that can be utilized legitimately in any current, unmodified diesel motor. Biodiesel is a perfect, inexhaustible and locally created diesel fuel, which has numerous attributes of a promising elective vitality asset. The most basic procedure for making biodiesel is known as transesterification. This process includes consolidating any characteristic oil (vegetable or creature) with practically any liquor, and an impetus. There are other thermochemical forms accessible for making biodiesel, however transesterification is the most regularly utilized procedure because of the effortlessness and high vitality effectiveness.

The fuel is dependent upon the lines of powers from perpetual magnets mounted on fuel supply lines. These states make the condition for more liberated relationship of fuel points of interest. The outcome of treating fuel with a high attractive field is improved burning of fuel and thusly expanded motor force just as diminished fuel utilization. Likewise the motor execution is significant to improve things proficiency of vehicle, it is understood by expanding the fuel property. Builds the rate in the total burning of the fuel in ignition chamber, here we present the magnet and their attractive field in the fuel inlet line flexibly.

### 1.1 Palm Oil [H.C. Ong et al ,2011]

Global demand for edible oil is increasing in this few decades which cause a tremendous increase in the area of oil crop cultivation especially soybean and oil palm. The world production of palm oil is 45 million tonnes and highest production is in South East Asia with a total 89% of total palm oil production (40% in Malaysia, 46% in Indonesia, 3% in Thailand) as shown in . In Malaysia a total 4.5 million hectares of land is occupied under oil palm cultivation. It produced 17.73 million tonnes of palm oil and contributed aboutRM65.19 billion to the Malaysia export in 2008. Malaysia has approximately 362 palm oil mills, processing 71.3 million tones of fresh fruit bunch and producing an estimated 19 million tones of crop residue annually in the form of empty fruit bunch, fibre and shell. Palm oil is one of the most efficient oil bearing crops in terms of land utilization, efficiency and productivity.

**Figure 1 Oil palm tree and fruits.**

**Table 1 The fuel Properties of Palm seed oil and Diesel**

| **Fuel Property** | **ASTM** | **Palm Seed Oil** | **Diesel** | **Unit** |
|---|---|---|---|---|
| Density at $15^0C$ | D4052 | 878 | 832 | Kg/$m^3$ |
| Kinematic Viscosity at $40^0C$ | D445 | 4.55 | 3 | cSt |
| Flash Point (PMCC) | D93 | 136 | 74 | $^0C$ |
| Fire Point | D93 | 153 | 120 | $^0C$ |
| Cetane Number | D613 | 62 | 51 | ---- |
| Gross Calorific Value | D4809 | 40582 | 43000 | Kj/kg |

**Table 2 compositions of fatty acid in palm oil**

| **Fuel** | **% in palm oil** | **Fatty acid** |
|---|---|---|
| Palmitic (C16)<br>Stearic (C18) | 32-45<br>2-7 | Saturated |
| Oleic (C18:1)<br>Linoleic (C18:2) | 38-52<br>5-11 | Unsaturated |

It is seen oil of palm has contained the most part on two fatty acids: oleic (18:1) and palmitic (16:0).The genuine extent in fatty acid is kept up steady after end of the reaction. In this manner, plainly palm oil advances maximum Impact on the earth and can meet a considerable extent of the energy of world.

## 2. Magnetic Fuel Energizer

**P. Govindasamy and S. Dhandapani (2007)"**Hydrogen occurs in two distinct isomeric forms one is para which is normally occurs in fuels, second is ortho which achieved by applying magnetic field. These two forms are characterized by the different opposite nucleus spins. The ortho state can be achieved by applying strong magnetic field along the fuel line **[2].**

**Farrag A.El Fatih, 2Gad M.saber (2010**) In the para Hydrogen molecule, which occupies the anti-parallel rotation, the spin state of one atom relative to another is in the opposite direction, therefore it is diamagnetic. In the ortho molecule, which occupies the parallel rotational levels, the spin state of one atom relative to another is in the same direction, therefore, it is paramagnetic **[3].**

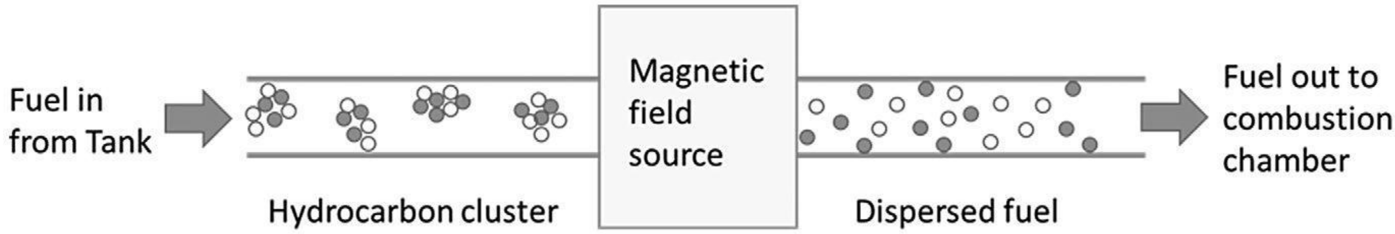


**Figure 1. Schematic figure of de-cluster process of fuel molecules due to magnetic exposure. [Nufus et al., *Cogent Engineering* (2017),]**

While the effect of magnetic exposure in reducing the fuel consumption has been proven, the explanation on the phenomenon is still unclear. Many researchers claim that the magnetic exposure can cause ionization in the fuel (Chaware, 2015; Okoronkwo, Nwachukwu, Ngozi, & Igbokwe, 2010; Singh & Solanki, 2015). Others claim the de-clustering effect and the reduction in size of a fuel's molecule constellation as shown in Figure 1 (Attar, Tipole, Bhojwani, & Desmukh, 2013; Jain & Deshmukh, 2012; Jundale, 2015). Accordingly, thorough study on the magnetic exposure on the fuel and logical explanation to the phenomenon is indispensably required. The clear explanation to the phenomenon will contribute to the development of the combustion technology that will significantly increase the effectiveness of combustion process. **[Nufus et al., *Cogent Engineering* (2017)]**

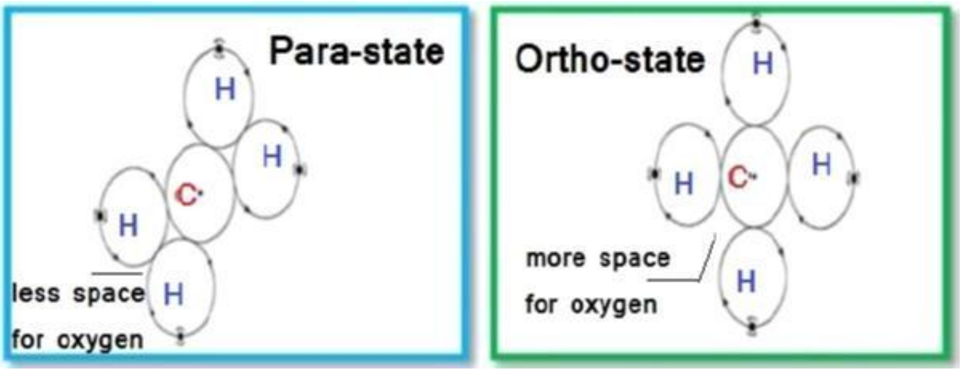


**Figure 2. state of diesel molecules**

When the fuel passes through a magnetic field, created by the strong permanent magnets, due to that magnetic field hydrocarbon change their orientation and convert from para state to ortho state . In ortho state inter molecular force is considerably reduced and increase space between hydrogen. This hydrogen of fuel actively interlocks with oxygen and producing a more complete burn in the combustion chamber. The magnetic field helps to disperse oil particles and to become finely divided. para state and ortho state of Hydrogen of clusters of hydrocarbons changed with the influence of magnetic field and they are more dispersed.

## 3. Experimental Set Up and Procedure

The performance tests were carried out on a single cylinder, four stroke water cooled Diesel engine. The setup consists of an engine, an eddy current dynamometer, and an exhaust gas analyzer. The engine was prepared to run on diesel as a fuel during all tests as shown in Fig.3. The fuel system is designed to facilitate for accurate measurement of the fuel flow rate. The fuel consumption is measured directly by using the burette method. The fuel consumption was measured at different engine loading conditions and exhaust gas measured by Exhaust gas analyzer. The exhaust gas analyzer is used to measure exhaust emissions from the engine during experimental tests as shown in Fig.3. It is measures gases such as HC, CO, $NO_X$ and $CO_2$ concentrations at each and every load. This procedure was done twice one for without magnet situation and other for with magnet situation, and results were compared.

**Figure 2 Experimental Setup**

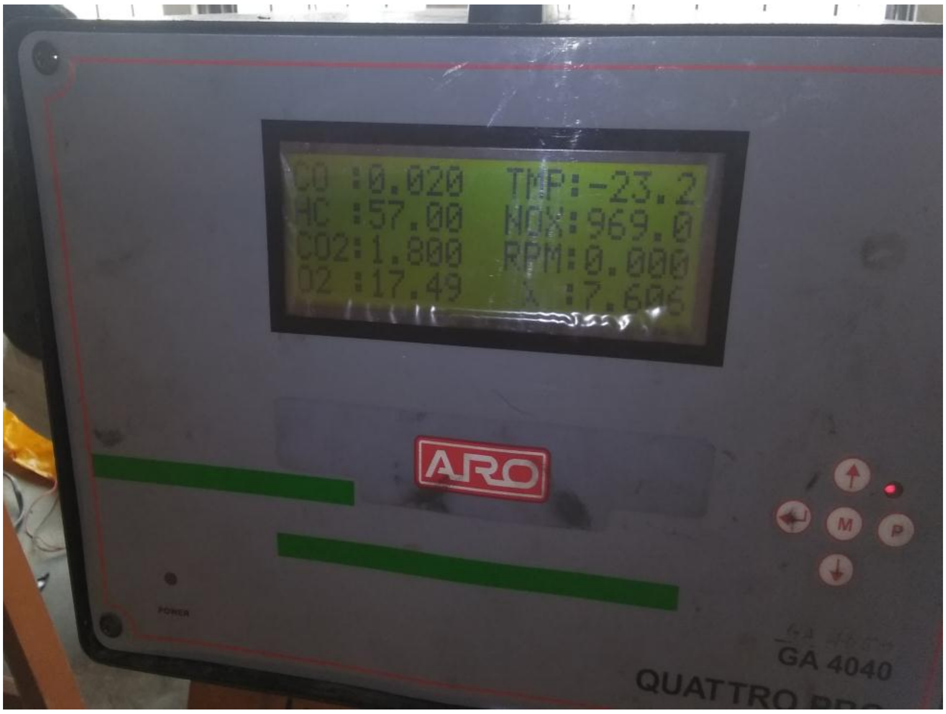


**Figure 3 Exhaust Gas Analyzer**

**Table 3** Technical Specification

| | |
|---|---|
| Engine manufacturer | Apex Innovations (Research Engine test set up) |
| Software | Engine soft Engine performance analysis software |
| Engine type | Single cylinder four stroke multi fuel research engine |
| No. of cylinder | 1 |
| Type of cooling | Water cooled |
| Rated Power | 3.5 kW @ 1500 rpm |
| Cylinder diameter | 87.5 mm |
| Orifice diameter | 20 mm |
| Stroke length | 110 mm |

| | |
|---|---|
| Connecting rod length | 234 mm |
| Dynamometer | Type: eddy current, water cooled, with loading unit |

**Table 4** Gas Analyser Specification for Ga4040

| Emission parameters | Measurement |
|---|---|
| Carbon Monoxide (CO) | 0 – 10% vol. |
| Hydrocarbons (HC) | 0 – 20000 ppm |
| Nitrogen Oxide (NOx) | 0 – 5000 ppm |
| Carbon Dioxide ($CO_2$) | 0 – 20% Vol |

**3.1 Properties of Magnet:** Neodymium Magnets also known as Neo magnet which is most widely used type of rare earth magnet and in bright silver colour as shown in Fig.4. This is a permanent magnet which made from alloy of neodymium, iron and boron and this magnet considered to be the strongest magnet type among other permanent magnet. This magnet widely used in electronic based companies and also as motor in cordless tools. The magnetic strength is 6000 gauss.

**Figure 4** Neodymium Magnet (6000 gauss)

**Installation Position:** It is just before the injector on inlet pipe or housing for maximum alignment & maximum effect.

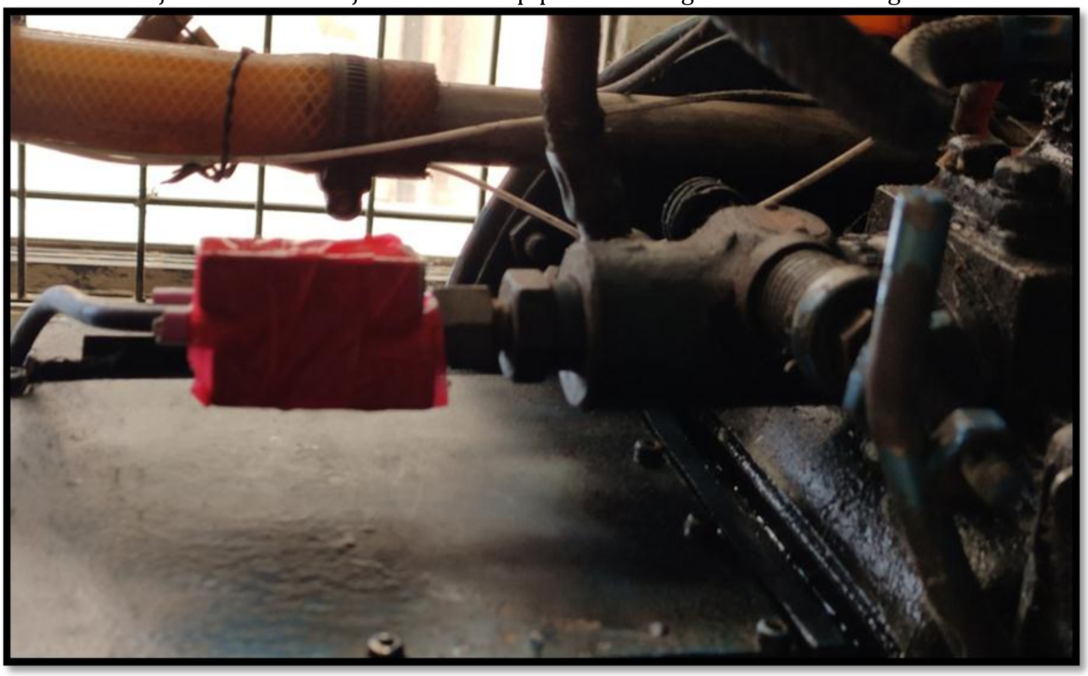

**Figure 5** Magnet Test Location

## 4. Results and Discussion

### 4.1 Engine Performance.

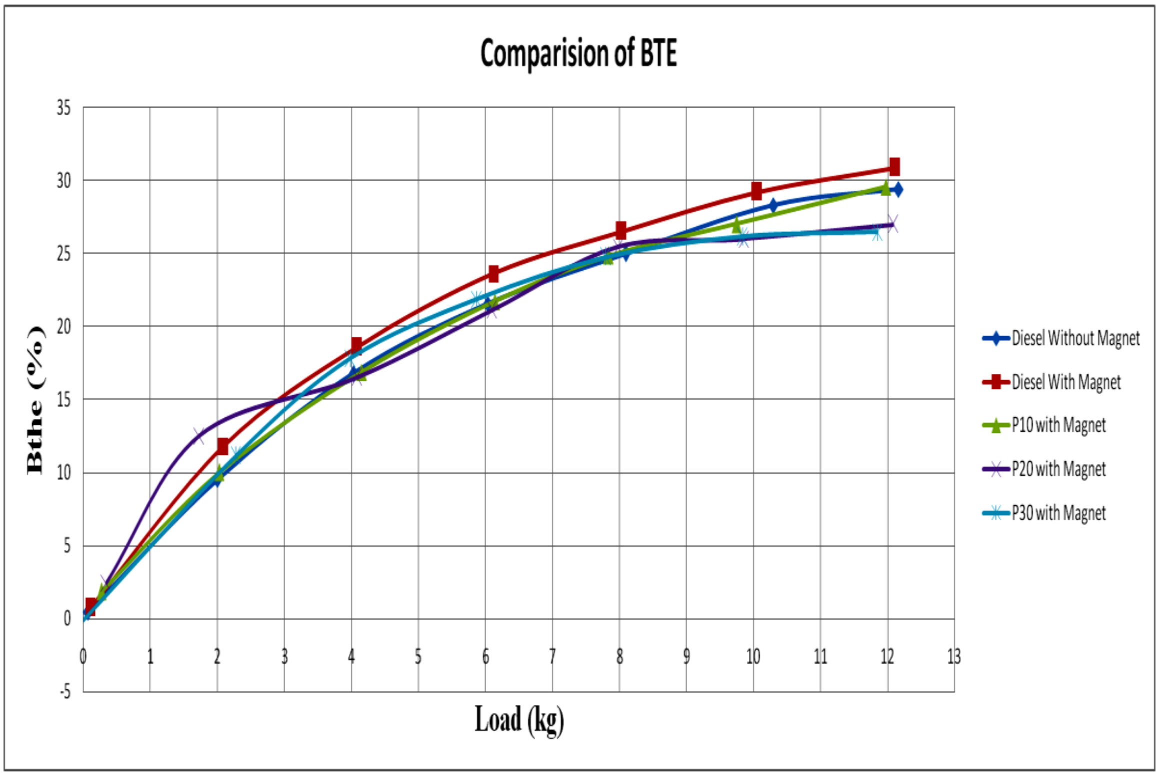


**Figure 6** Variation of Brake Thermal Efficiency for Test Fuel at different Load

(1) **Brake Thermal Efficiency**:- It is seen from the fig.6 that for all the fuels BThEff. Increases with increase in load. It is also observed that blend P10 with magnet and diesel with magnet have a maximum BThEff. The BThEff. is higher for diesel with magnet 29.86 at full load . . The BThEff of blend P10 is higher than pure diesel without magnet. Comparing BTE of diesel engine for pure diesel as fuel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss, there is a reduction in BTE at partial load for P20 blend 2.13% wheras rise in BTE for D100, P10, P30 by 9.50%, 0.78% , 1.43% and at full load rise in BTE for D100 and P10 by 5.03% , 0.57% wheras reduction in BTE for P20and P30 by 8.22%, 10.02% .

Combustion chamber design, injection nozzle type, pressure of injection affects BTE. In addition to this, fuel and spray attribute like volatility, viscosity, cetane number, formation of uniform mixture, CV and vaporization latent heat also influence it. The BTE varies with load. At part load its deviation is more than full load due to the elevated temperatures inside the cylinder. BTE of diesel and blends with biodiesel were seen rising with step up in load, but tended to reduce with further step up in load. It is higher for diesel compared with biodiesel and its blends due to its high calorific value, perfect combustion and forming of high temperature (Naidu, 2014). *Due to lower volatility, high viscosity* and imperfect combustion lead lower the BTE of all blends.

(2) **Specific Fuel Consumption :** Figure 7 shows the SFC variations with respect to load applid for all tested fuels. It is clear from the graph that SFC decreases with increase in load. It is observed that diesel with magnet and P10 shows the minimum SFC for full load. Comparing SFC of diesel engine for pure diesel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss. And for P10, P20,P30 there is rise in SFC of engine at partial load by 0%, 5.26%, 0% and at full load by 0%, 10.71%, 14.28% respectively .And for magnetized D100 fuel there is reduction in SFC at partial load by 7.89% and at full load by 3.57%.

The deviation in BSFC, with load for various fuels shows declines with step up in load due to enhancement in brake power with load as comparing the consumption of fuel. The BSFC of all blends compared with diesel for all loads, due its high density, poor heating value and consequently high bulk modulus lead to flowing of more fuel from the injection pump for same plunger displacement, resulting stepping up in SFC (Dharmadhikari, 2012).

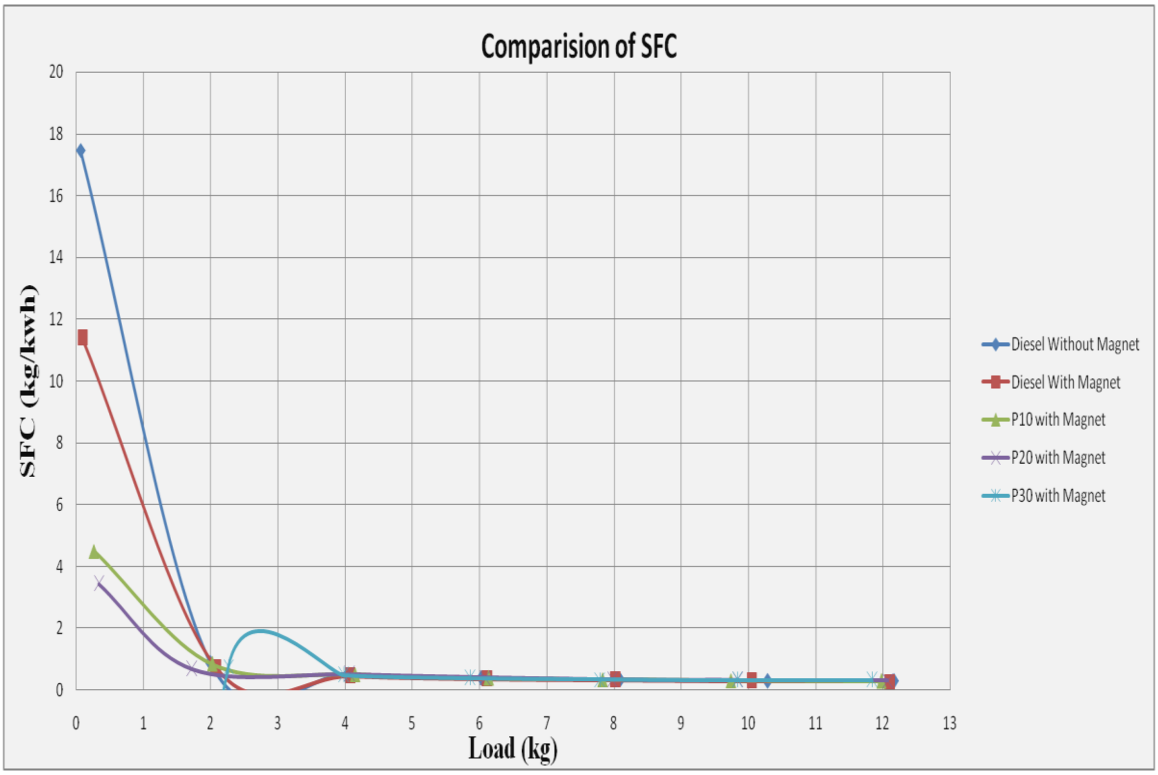


**Figure 7** Variation of Specific Fuel Consumption for Test Fuel at different Load

(3) **Indicated Power**:- Figure 8 shows the variation of indicated power for test fuel at different load condition. From figure it is clearly shows that IP For diesel fuel increased continuously for no load to full load condition. And for D100 without magnet IP increased higher than other fuels.. The Indicated Power of the engine is depends on friction power and brake power of engine. When friction power decreased than got better indicated power. Comparing IP of diesel engine for pure diesel as fuel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss, there is a reduction in IP at partial load by 11.95%, 3.21%, 20.45%, 35.86% and at full load by 9.09% , 4.95%, 16.03%, 27.10% in that order.

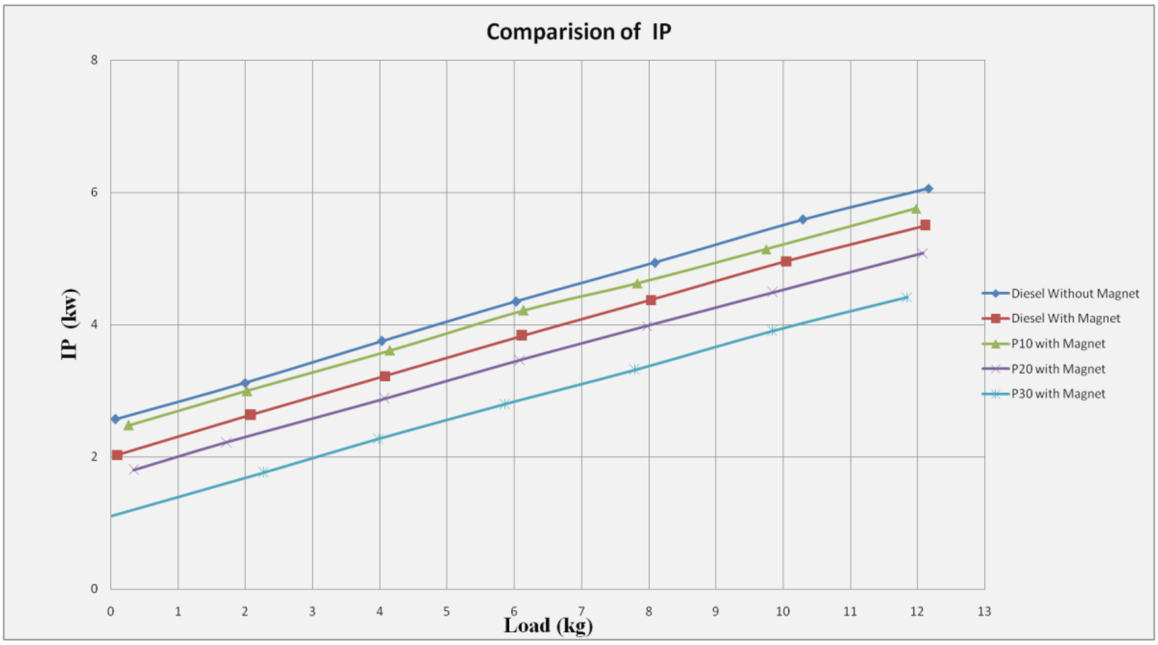


**Figure 8** Variation of Indicated Power for Test Fuel at different Load

### 4.2 EXHAUST EMISSION

(1) **NOx (Nitrogen Oxide)**:- From the fig 9, it is concluded that the Nox emmision with P20 and P30 with magnet are lesser than others. And P30 with magnet have lowest NOx emission at all varying loads. Comparing NOx emission of diesel engine for pure diesel as fuel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss, there is a reduction in NOx emission at partial (66%) load by 10.87%, 33.57%, 30.41%, 38.16% and at full load by 3.61% increased NOx while reduction of NOx 22.69%, 21.28 %, 25.40% in that order. NOx emissions produced by the engine will decrease with the use of biodiesel for several reasons . The higher cetane numbers of the biodiesels, as compared to neat diesel fuel, can decrease Nox emissions (relatively lower ignition delay and, thus, shorter premixed combustion, during which NOx is mainly formed), and also contributes to the absence of aromatic compounds from the biodiesels.

Inbuilt oxygen is more effective than the supply of oxygen from outside (Aydin H, 2010). Delay of energy release due to slow combustion process of Karanja/palm oil blends with diesel produce high temperature later part of stroke of power and concentration of oxygen in biodiesel leads to formation of NOx (Naik, 2013)

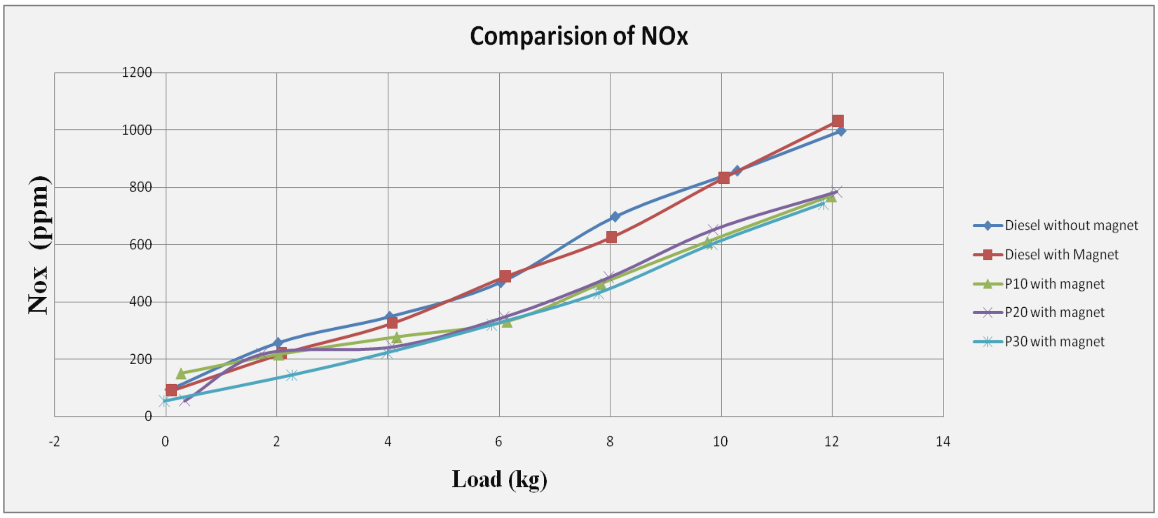


**Figure 9** Variation of NOx for Test Fuel at different Load

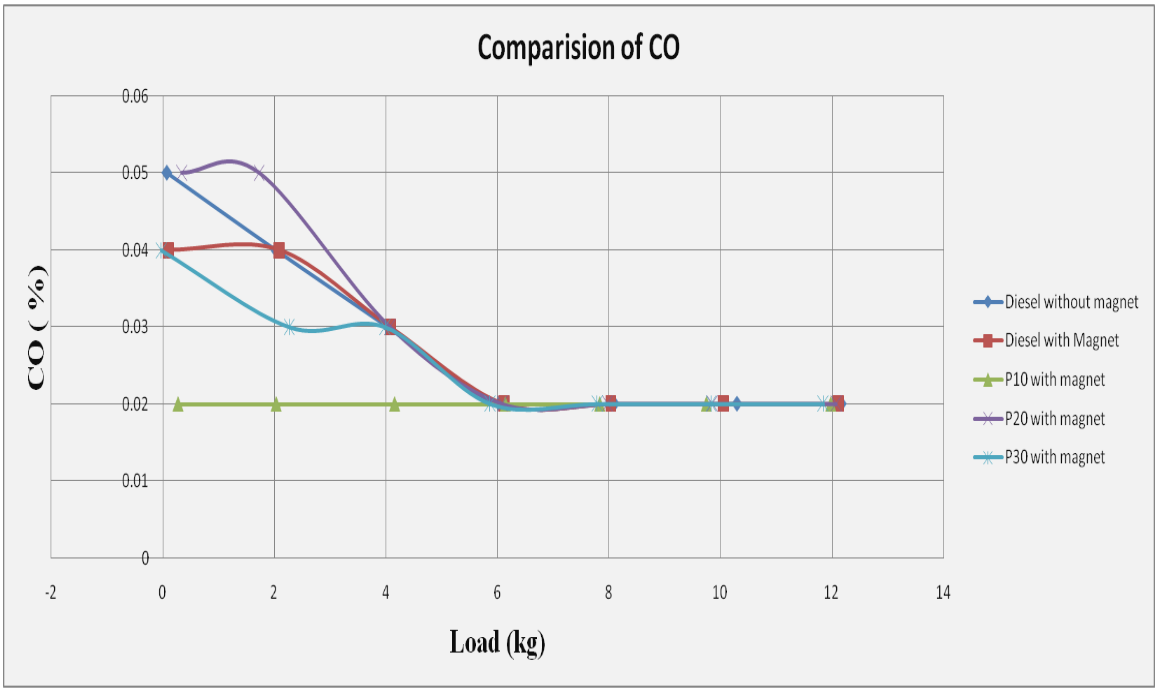


**Figure 10** Variation of Carbon Monoxide (CO) for Test Fuel at different Load

(2)**CO (Carbon Monoxide):- ):** From the fig. 10, it is observed that CO emission decreesed with incresed of engine load. Compared to others blends, P10 with magnet have lowest CO emission at all varying loads. From above results, it is clear that for load from 6kg to 12kg are lower CO emission due to the magnetic effect. Comparing CO emission of diesel engine for pure diesel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss there is reduction in CO emission of engine at partial load by 0% and at full load By 0%respectively.

*Higher viscosity and lower CV leads of blends leads to imperfect combustion resulting increasing emission, but oxygen present in biodiesel improves the combustion process which in turn high temperature of combustion chamber so oxidation of CO* (CO to CO2)*better ,resultingreduction of CO emission*(Naidu, 2014)(Gumus M, 2010). A rich zone of fuel forming decreases due to the high Cetane number leading to reduction of CO (Xue, 2011).

(3)**$CO_2$ (Carbon Dioxide):-** Fig.11 shows the variation of a Carbon Dioxide for test fuel at different load condition Comparing CO2 emission of diesel engine for pure diesel as fuel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss, there is a reduction in CO2 emission at partial load by 0.00%, %, 14.28%, 14.28%, 21.42% and at full load by 0.00% , 21.05%, 21.05%, 15.78% in that order. It can be pragmatic that CO2 steps up with step up in load for all fuels tested.

The trends observed may be because of more fuel being burnt at higher loads due to which more carbon is available to form CO2. It is seen that due oxygen content in biodiesel and its blends, reaction of oxygen with carbon atoms which is not burnt occur during combustion leads step ups the CO2 formation than diesel which denote complete combustion of fuel (AK. A. , 2007).

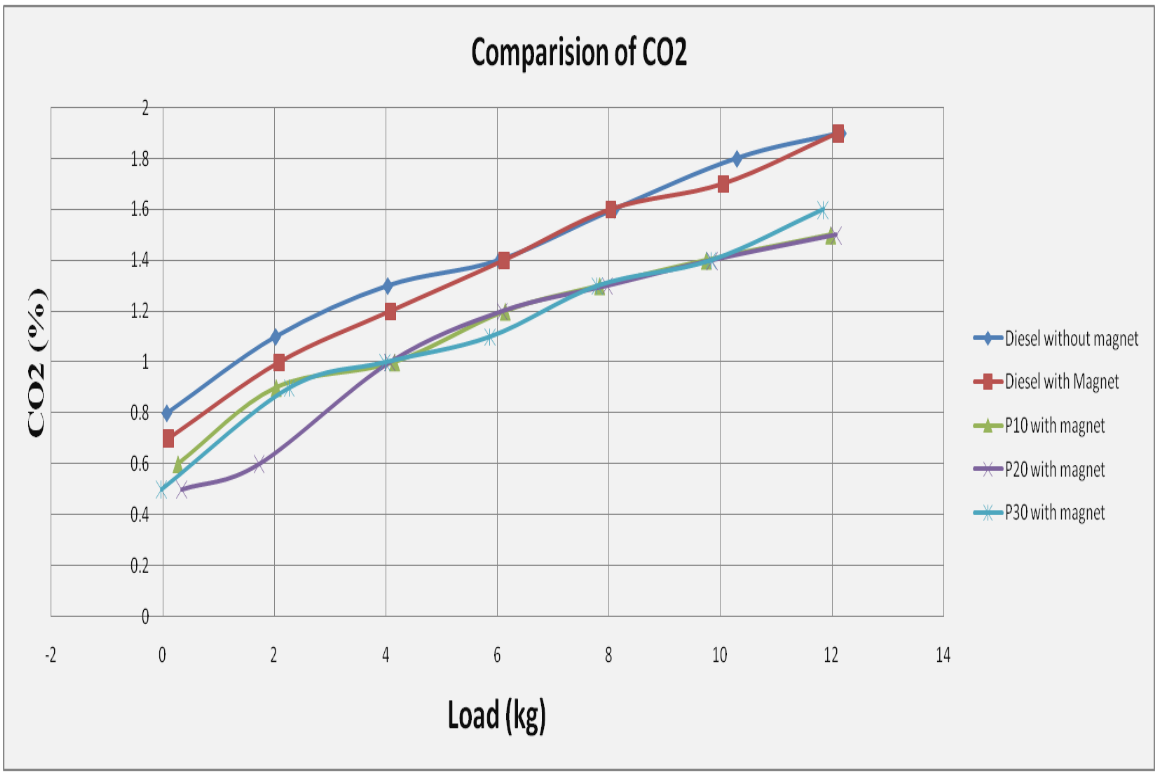


**Figure 11** Variation of Carbon Dioxide ($CO_2$) for Test Fuel at different Load

(4)**HC (Hydro Carbon):-** Comparing HC emission of diesel engine for pure diesel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss there is reduction in emission at partial load by 19.60%, 64.70%, 68.62%, 62.74% and for D100 at full load by 14.70% rise in HC emission and there is reduction in HC emission 57.35%, 58.82%, 44.11% respectively.

The HC emission steps up with step up load on the engine. Blends quality like the content of oxygen, viscosity which leads to atomization effect on HC emission. Lower CV leads higher requirement of fuel for same load which in turn more viscosity which responsible for poor atomizing and combustion, increasing HC but high oxygen which increase fuel oxidation (AK. A. , 2007), high cetane number, in blends shorter ignition delay, perfect combustion and high temperature reduces HC emission than diesel fuel (Naidu, 2014)(Dharmadhikari, 2012)(Monyem A, 2001)(Lapuerta M, 2008).

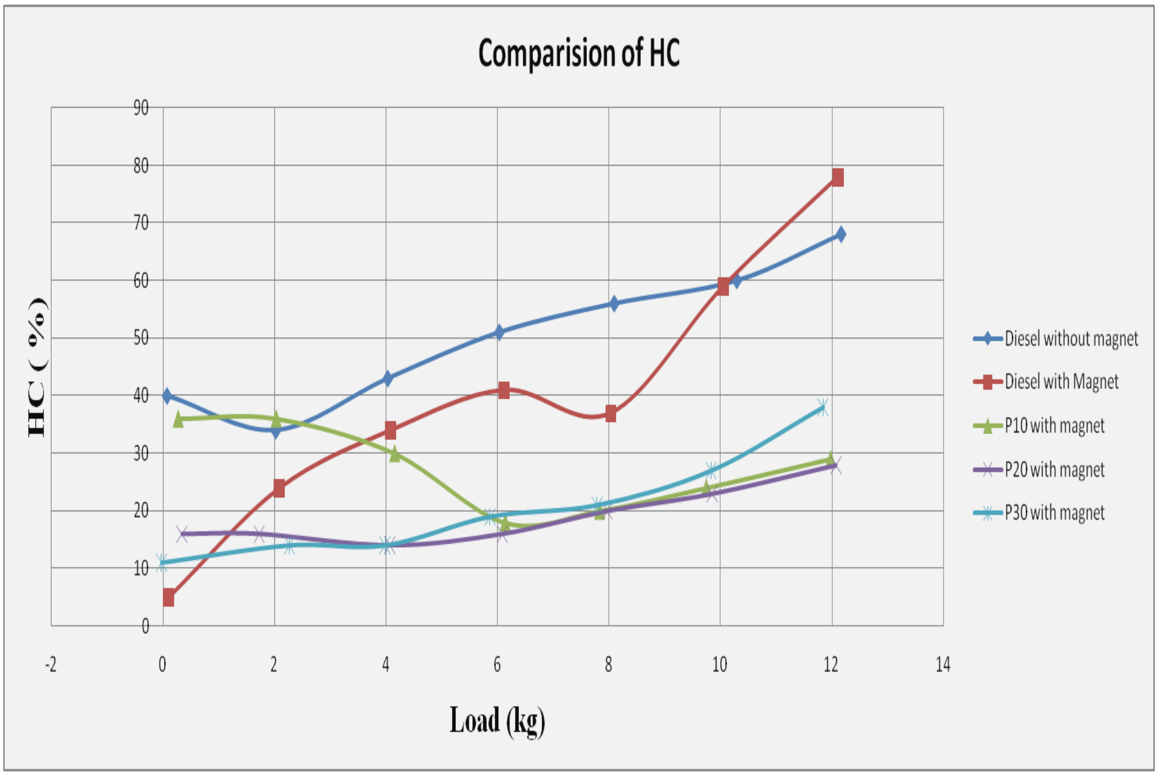


**Figure 12** Variation of Hydro Carbon (HC) for Test Fuel at different Load

## 5. CONCLUSIONS

Comparing performance and emission of diesel engine for pure diesel to D100, P10, P20, P30 blended magnetized fuel with Neodymium-Iron-Boron based magnets of 6000 gauss following conclusions were made:

- There is a reduction in BTE at partial load (6kg) for P20 blend 2.13% wheras rise in BTE for D100, P10, P30 by 9.50%, 0.78% , 1.43% and at full load (12kg) rise in BTE for D100 and P10 by 5.03% , 0.57% wheras reduction in BTE for P20and P30 by 8.22%, 10.02% .
- And for P10, P20,P30 there is rise in SFC of engine at partial load (6kg) by 0%, 5.26%, 0% and at full load by 0%, 10.71%, 14.28% respectively .And for magnetized D100 fuel there is reduction in SFC at partial load by 7.89% and at full load by 3.57%.
- There is a reduction in IP at partial load (6kg) by 11.95%, 3.21%, 20.45%, 35.86% and at full load (12kg) by 9.09% , 4.95%, 16.03%, 27.10% in that order.
- There is reduction in CO emission of engine at for P10 at 4kg load by 33.33% and at full load (12kg) By 0% for all blends .
- There is reduction in HC emission at partial load (6kg)by 19.60%, 64.70%, 68.62%, 62.74% and at full load by 14.70% rise in HC emission and at full load there is reduction in HC emission 57.35%, 58.82%, 44.11% respectively.
- There is a reduction in CO2 emission at partial load by 0.00%, %, 14.28%, 14.28%, 21.42% and at full load by 0.00% , 21.05%, 21.05%, 15.78% in that order.
- There is a reduction in NOx emission at partial (66%) load by 10.87%, 33.57%, 30.41%, 38.16% and at full load by 3.61% increased NOx while reduction of NOx 22.69%, 21.28 %, 25.40% in that order.

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## Abbreviations

$CO_2$ - Carbon Dioxide

CO - Carbon Monoxide

NO - Nitric Oxide

HC - Hydrocarbon

BSFC - Brake Specific Fuel Consumption

BP - Brake power

BTE - Brake thermal efficiency

PM - Particulate Matter

PPM - Parts Per Million

HC - Unburned Hydro Carbons

$NO_x$ - Oxides of Nitrogen

EGT - Exhaust gas Temperature